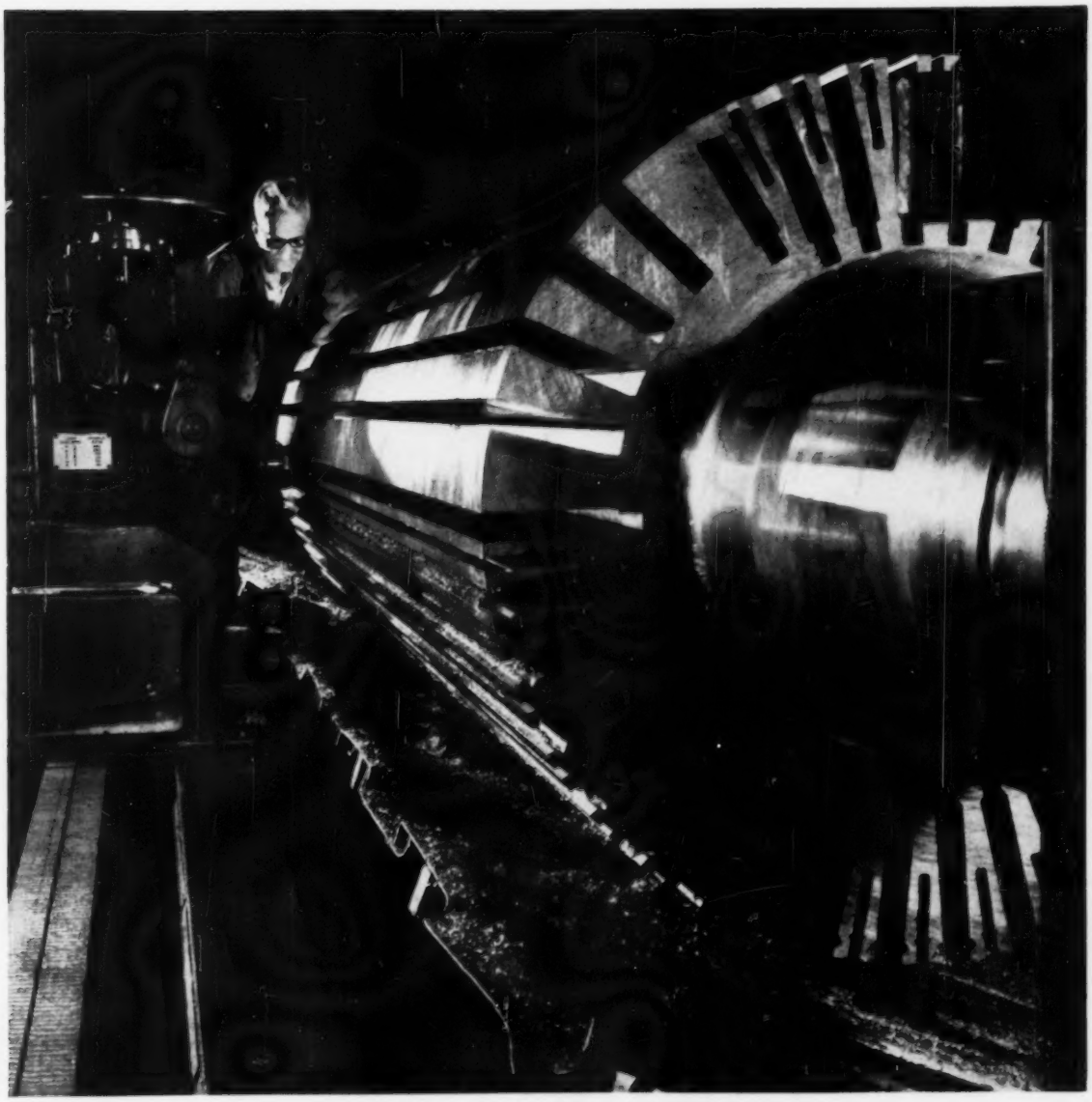
THE BEAMA JOURNAL

NOVEMBER 1961



Machining the rotor of a large alternator

A QUARTERLY REVIEW OF

BRITISH ELECTRICAL AND ALLIED ENGINEERING

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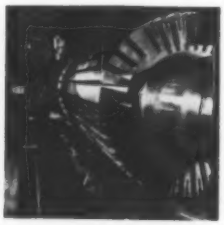


Cover Illustration. *A machining operation in progress on the rotor of a 120 MW alternator in one of the factories of Associated Electrical Industries Ltd. The alternator is part of one of two turbogenerator sets ordered by Elektrim of Poland*

Editor: **John Dyer**

Published by The British Electrical and Allied Manufacturers' Association (Incorporated), 36 Kingsway, London, WC2. *Telephone:* HOLborn 0502. *Telegrams:* Perisirius, Westcent, London.

Annual subscription: 10/- post free. Single copies, 2/6. Advertising rates on application. Publication dates: February, May, August, and November.

The Association does not necessarily endorse statements made in the Journal.

THE BEAMA JOURNAL

A QUARTERLY REVIEW OF BRITISH ELECTRICAL AND ALLIED ENGINEERING

Volume 68 : Number 4 : November 1961

The BEAMA Directory

ONE of the important events in this BEAMA Golden Jubilee Year is the publication of the first edition of the new BEAMA Directory, which has been planned specifically to bring the story of the British electrical and allied industry and its products to the electrical markets of the world. As such, it will provide another important and valuable service to buyers and users of electrical equipment overseas.

With a page size of 8½ by 5½ inches (216 by 140 mm), the new Directory has been designed to meet the wishes of BEAMA member-firms and users for a more compact and convenient trade directory and buyers' guide which also includes multi-lingual sections arranged for quick and easy reference by overseas buyers.

An important innovation is the inclusion of Russian in the foreign language reference section in addition to French, German, Portuguese and Spanish. Each language forms a self-contained section on distinctively coloured paper, and a cross-reference system enables foreign readers to locate easily the sources of supply of more than 1 000 items of British electrical and allied equipment listed in the classified buyers' guide section.

This first edition also contains two special features. The first is the story of the phenomenal development of the British electrical industry over the last 50 years. The second is a series of dramatic impressions, in the spirit of the Jubilee Year, which attempt to recapture the atmosphere of various aspects of the industry in the first year of the 50-year period (1911), in striking contrast with the facing pages showing corresponding achievements in 1961.

Following this historical section come, first, the Directory of Manufacturers, listing the addresses, telephone and telex numbers and cable addresses of BEAMA member-firms, together with their overseas branches and agents; second, the advertisement section; third, the Classified Buyers' Guide; fourth, the five-language reference section in French, German, Portuguese, Russian and Spanish.

The initial distribution of the Directory will be free to a carefully-compiled mailing list including Government establishments, electricity undertakings, importers, agents, and similar concerns in most countries of the world, on the basis of one free copy to each recipient. Additional copies may be purchased at £3 sterling or $10 each, and orders should be sent either to The BEAMA or to the distributors—the Pergamon Press Ltd at Oxford, England, or at any of their overseas branch offices, the addresses of which appear in the Directory.

The new Directory continues the work of The BEAMA Catalogue which, after four editions in 1948, 1952, 1955 and 1958, has become widely known and firmly established all over the world as an authoritative and comprehensive source of information on the British electrical and allied industry, its products and sources of supply.

It thus provides another important stimulus to the flow of trade from Britain to countries overseas and a valuable adjunct to the many services operated by The BEAMA to assist both the overseas buyers and the British electrical manufacturers.

Mr Leonard H. Short, Chairman of The BEAMA Export Panel, disclosed the record figures of British electrical and allied engineering exports for the first nine months of this year when he presented the first copy of the Directory to Sir Keith Joseph, Bt, Minister of State, Board of Trade. Shipments for the period in question amounted to £238 million—£22 million more than the first nine months of last year and £27 million more than in 1959. This is an increase overall of 10 per cent, but shipments to the countries of the European Common Market showed the even more spectacular increase of 45 per cent.

Mr Short also announced that the domestic electrical appliance section of the industry will be staging its biggest-ever display in Europe at the International Household Goods and Hardware Fair in Cologne in February next, and among other plans for next year is a large BEAMA exhibit, in co-operation with the British Board of Trade, in the British Pavilion at the International Trade Fair to be held in Lagos, Nigeria.

In these and other ways, The BEAMA is assisting the British electrical and allied industry to bring increasingly to the countries of the world the benefits of its great resources and unrivalled technical skill in every field of the generation, transmission and utilisation of electricity.

Five Years of Calder Hall

FIVE years ago—on October 17, 1956—Her Majesty the Queen opened Calder Hall, Cumberland*, the world's first industrial scale nuclear power station. These five years have shown successful results which have proved useful from many points of view. In the experience gained from operating these reactors and the experimental work involved, substantial aid has been given throughout the world in the development of nuclear power. Since the four atomic reactors at Calder Hall and the four similar reactors at Chapelcross, Scotland, were brought to the stage of criticality, they have exported to the national grid 5 920 million kilowatt-hours of electricity. Of this total, Calder Hall contributed 3 729 million kilowatt-hours.

The eight Calder Hall and Chapelcross reactors have now accumulated between them over 24 reactor years of operating experience, and extensive investigation has revealed no reason to doubt that they will achieve their 20 years designed life.

Five years ago, few could have foreseen the achievements in Calder Hall and Chapelcross that have developed in so short a time. First, the heat and electrical output have considerably exceeded design expectations; second, reliability in continuous operation and reduction of fuel changing and maintenance shut-down periods have been such as to achieve load factors of over 85 per cent, even though all fuel changing has to be carried out with the reactors shut down. This compares favourably with the best capability of the latest coal-fired stations. Third, the magnox-canned uranium fuel elements have successfully withstood periods of irradiation in the reactors for longer than they were designed to achieve, without significant increase in fuel element failure rates, and fourth, these results have been achieved despite extensive use of the reactors for experimental work in aid of the larger nuclear stations now commissioning or under construction.

With operating experience, it has proved possible to step up heat and electricity output in stages to a level well beyond expectation. Specifically, the heat output per reactor is now running at about 220 MW compared with the designed output of 180 MW—an improvement of nearly 25 per cent. This increased rate of heat output outstripped the capacity of the turbo-alternators to convert the heat for electricity. In consequence, the programme of reblading turbines to increase their capacity to 27 MW (electrical) from 23 MW (electrical) is well on the way to completion.

One of Calder Hall's four reactors completed, on January 31, 1961, a 12-month period of continuous operation on the same fuel charge, without once having to be shut down because of failure of fuel elements. This is a remarkable achievement, considering that the reactor contains about 10 000 fuel elements, that it had been maintained on full load for 95.6 per cent of the period, and that more than half of the remaining 4·4 per cent of the time was accounted for by experimental work.

The reliability in operation of the reactors is largely due to the high standards of maintenance engineering and to the soundness of the original design and construction. Improvements both in the machines themselves and the method of their use for charging and discharging fuel, and streamlining the programme maintenance operations, have resulted in reducing the shut-down periods for fuel changing and maintenance from the original 11 weeks to four weeks at the present time. This, of course, has led to a significant step-up in the load factor, and an average load factor of 88 per cent has been achieved over the past 12 months. No faults in the reactor system as such have occurred to date.

Experimental work in aid of the nuclear power programme has proved to be of the greatest use. Irradiation in the Calder reactors of prototype fuel elements for the Bradwell and Berkeley nuclear power stations which will shortly be in operation played a significant part in establishing small but important design improvements incorporated in the fuel elements for those stations.

The Calder reactors have also been used for advanced testing of the actual fuel to be used in the nuclear power stations in Great Britain. An example was the study of the effects on fuel element endurance of the thermal changes which will result from on-load fuel changing at these later stations.

In addition to the many British personnel who have been trained in, and attached to, the United Kingdom Atomic Energy Authority's design offices, many concerns from 30 countries have sent students to be trained in reactor operation at the Calder Hall operational school,† and on the reactors themselves. Some 60 operators for the British-designed Latina nuclear power station in Italy and the Tokai Mura station in Japan have also benefited from these studies. Brazil, India, Argentina, Ceylon and Greece are among the countries who have sent students.

Much of the successful operation of Calder Hall is due largely to the British manufacturers of the equipment that changed Calder Hall from a blue print into reality. Their research over many years, and the extensive development work they are constantly carrying out, have been a dominant factor in ensuring that the operation would be the success that it is today.

Each stage of progress from the Calder Hall reactors poses increasingly advanced problems of many kinds, particularly investigation of properties and compatibility of materials and development of methods of fabrication. But if the past five years' operating experience, which has proved so successful, is an omen for the future, then the designing, planning, and the experimental work will prove of great value to every country that believes that the peaceful use of atomic energy can be of great benefit to mankind.

* THE BEAMA JOURNAL, **63**, No 1, pp 16–18

† THE BEAMA JOURNAL, **68**, No 3, p 96

Developments in High-voltage Air-blast Circuit-Breakers

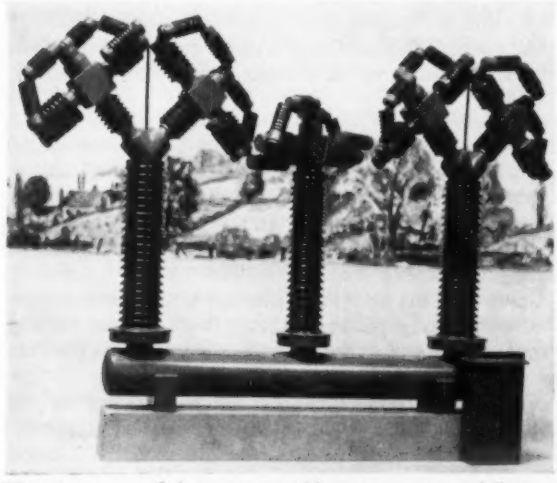
IN step with the advances in power generation has been the growth in many parts of the world in systems for the bulk transmission of power over great distances and at progressively higher voltages. In the U K, for example, transmission voltages have increased from the 132 kV of the original grid to 275 kV for the super-grid inaugurated in 1953, and now to 400 kV for the new super-grid scheduled to start operating in 1965. This latest increase of 125 kV, coupled with a higher current rating, will almost treble the power-carrying capacity of the new super-grid.

British manufacturers have foreseen this trend and some years ago embarked on an extensive programme of research and development in insulators, cables, circuit-breakers and allied equipment, several aspects of which have been recorded in recent issues of THE BEAMA JOURNAL.

Among them is the English Electric Co Ltd, who decided early in 1957 that an entirely new circuit-breaker would be necessary to meet world requirements for breakers with a very high performance at the highest voltages, and a performance specification was laid down for a range of air-blast circuit-breakers suitable for voltages from 132 kV up to 650 kV and possibly higher, current ratings of 2 000 A and 4 000 A, short-circuit ratings up to 50 to 60 kA, and very short total break times.

The result is the new frame 'r' air-blast circuit-breaker described in this article.

The most important order for it—the first 400 kV switchgear for the C E G B, valued at about £1½ million—



This shows one of the many possible arrangements of the new frame 'r' breaker—a 10-interrupter breaker in 'YT' formation suitable for operation at 400 kV 35 000 MVA or 500 kV 30 000 MVA

was placed this year, covering thirteen 35 000 MVA air-blast circuit-breakers, eight of which will be rated at 4 000 A and five at 2 000 A, together with the power-operated isolators and other apparatus to form a complete duplicate busbar switching station. The equipment will be installed at the new power station at West Burton in Nottinghamshire.

Special equipment necessary to test these new breakers has been installed at the company's Nelson High Power Laboratory in Stafford.

English Electric pioneered the commercial application of air-blast circuit-breakers in the U K and in 1940 supplied a 6·6 kV 150 MVA air-blast circuit-breaker for controlling the arc furnace transformer in a large steel works. A complete range of air-blast breakers was subsequently developed and in 1947 the first 132 kV air-blast breaker was installed on the British grid; this design was later extended to 275 kV.

All these breakers are of the conventional design, with the compressed air stored in receivers at ground level, blast valves located at the base of the support column, and 'make' switches. In this design the interrupters are subjected to air at high pressure only when opening, and two factors affecting the performance are first, the time taken for the compressed air to travel from the receivers to the interrupters via the blast valves, and second, the pressure drop that occurs, so that the actual air pressure at the contacts is lower than the storage pressure. These two factors are, of course, inherent in all air-blast breakers with air storage at ground level and upstream blast valves, whether or not the contacts are pressurised in the open position.

Development of the Frame 'r' Breaker

Development of the frame 'r' breakers has continued steadily since 1957 against the background of the extensive experience already gained on older designs, and based on the following principles:

The various ratings would be met by the use of multiples of a unit interrupter, connected in series horizontally, and thus capable of extension to the highest voltages.

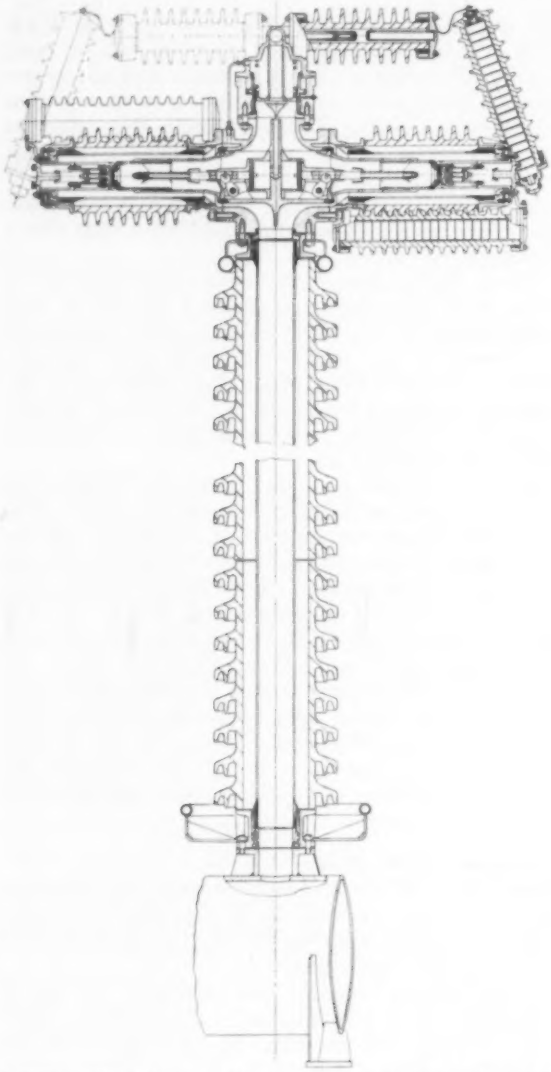
The breaker would be manufactured on the unit basis, each unit being fully works-tested separately.

The contacts would be pressurised at full air pressure both in the open and closed positions, which in turn involves a downstream blast valve. This means that full air pressure is available at the interrupter contacts at all times.

The breaker would be controlled and operated mechanically right up to the pilot valves located at line potential adjacent to the blast valve. This cuts out the time-delay mentioned earlier and ensures very fast operating times at all voltages and under all conditions.

As the contacts are pressurised in the open position, the 'make' switch—which presents difficulties at the high ratings—would be dispensed with.

The other main features of the frame 'r' breaker are: arcing contacts do not part until approximately half the travel is completed, and thus the speed of opening is greatly increased; height has been kept to a minimum; appearance is neat and clean; all parts easily accessible for inspection and maintenance; unit construction permits variations in assembly; two arrangements of interrupters available, namely 'Y' and 'T'; breakers may consist entirely of either the 'Y' and 'T' interrupter formations, or of a combination of both to suit any rating within a minimum of space.



A cross-section (shown in third angle projection) of a frame 'r' 'T' type pole with 'C' type interrupters

The result is that full operating pressure is available at the contacts and there is no pressure drop or time-delay in filling support insulators such as occurs with breakers having blast valves located at the receiver.

The mechanism ensures very short opening times, and the combined effect is a guaranteed 2·5 cycle operation at any voltage and extremely good interrupting performance, which is particularly noticeable on line charging and capacity currents.

The omission of the 'make' switch minimises air consumption and eliminates external moving parts which might be subject to the possibility of icing and other adverse weather conditions.

Interrupters can be arranged either in 'Y' formation (four interrupters per support column) or in 'T' formation (two interrupters per column) or in combination of both, as shown in the accompanying photographs.

It will be appreciated that many other arrangements are feasible, and that for breakers with two or four interrupters per phase all three poles can be accommodated on one air receiver.

The high-pressure air at 300 lb/in^2 (14 kg/cm^2) is contained inside the support columns and interrupter porcelain within epoxy resin-bonded glass tubes. These tubes, by means of pre-tensioning, hold the outer porcelain weather sheds in compression. The outer space between the tubes and porcelain is permanently air-conditioned at a positive pressure of 2 lb/in^2 (141 g/cm^2) above atmospheric.

Operating Mechanism

The operating mechanism is a small pneumatically-operated spring trip mechanism of the type used successfully for many years in oil circuit-breakers. It is located in a cabinet attached to the main air receiver of one phase and operates control levers, situated in a box on the centre casting of each pair of interrupters, by means of epoxy glass-fibre rods located in the air-conditioned space between the porcelains and main epoxy resin-bonded glass tubes. These rods are spring-loaded so that there is no lost motion due to slack.

To initiate a trip operation, the shunt trip coil is energised and so releases the latch; then by means of the epoxy glass-fibre rods, the subsequent motion causes the master levers in the interrupter control boxes to depress the pilot trip valves which in turn feed the blast valves.

To close the breaker, the mechanism restores the rods to the latched position, thus causing the master levers to depress the closing valves in the interrupter control boxes.

Interrupters

These are built in pairs, with one blast valve and control mechanism per pair of interrupters. They consist of a cylindrical fixed main contact which houses a spring-loaded arcing contact, and a moving throat which is located in a second cylinder attached to the centre casting.

Opening of the blast valve drains the air from the back of the operating pistons and the back of the moving throat, and so causes the latter to move inwards towards the centre of each interrupter pair.

The main current-carrying contacts part, leaving the circuit made through the arcing contacts. The spring-loaded arcing contact is arrested at about half the travel distance of the moving throat, thus providing a high-speed break. The arc is drawn, transferred to the arcing tips, and extinguished by the flow of air through the nozzle.

Levers attached to the moving shaft drive over-toggle a spring-loading device which mechanically holds the contacts either closed or open and prevents contact movement in the event of an air leak. The same movement via a lever resets the master operating lever to the neutral position ready for closing; this allows the pilot valve and consequently the blast valve to close.

The whole of the interrupter space is then re-pressurised to full pressure, so that the breaker in the open position will withstand full system voltage.

When the closing valve is operated as described above, it drains the space in front of the operating pistons to atmosphere, and the differential pressure causes the moving throats to close. Making is effected on the arcing contacts under full pressure with negligible pre-arcing, and the spring-loaded arcing contact is then driven home, allowing the main current carrying contacts to make.

The levers return the over-toggle spring device to its original position and reset the master lever in the neutral position ready for tripping, thus allowing the closing valve to close.

High Speed Auto-Reclose

Immediately following each operation, the control mechanism and contacts are ready for the next operation. The mechanism itself is of the quick-reset pattern and thus only the addition of an auto-reclose timing relay is necessary. Dead times down to 10 cycles or even less can be attained, and by means of the relay any higher dead times can be used.

Due to the inherent design features, arcing times are kept to the minimum—*i e* one loop, and the breaker has a total break time of 0·05 seconds maximum—*i e* 2·5cycles on the 50 c/s basis. Performance on line-dropping is extremely good because of the high pressure and fast break, and the breaker is re-strike free.

Resistance Switching

The breaker can be equipped with two types of resistor: light-duty and heavy-duty.

Heavy-duty resistors are required for making the breaker suitable for interrupting short line faults where the short-circuit duty per interrupter is particularly high. The performance of the interrupter is so good that it is only for the more onerous short-circuit levels that these are required and then it is not necessary to apply full critical damping of the line side transient, but sufficient damping to bring the rate of rise of re-striking voltage within the capability of the interrupters.

Light-duty resistors can be employed in all other cases, their function being to ensure voltage division between interrupters when the breaker is breaking current and to damp out over-voltages when the breaker is switching low inductive currents.

Both sizes of resistor require resistor interrupters and these are automatically switched on operation of the last valve.

The two sizes of resistor and their associated resistor interrupters are interchangeable, and it may well be both economical and the best technical arrangement to fit heavy-duty resistors only to those breakers which can switch transmission lines; all other breakers, *e g* transformer breakers, having the light-duty higher ohmic value resistors.

Capacitors are fitted across the interrupters to ensure even voltage distribution in the open position. They also help the resistors in this duty when the breaker is opening the circuit.

Testing High-Voltage Circuit-breakers

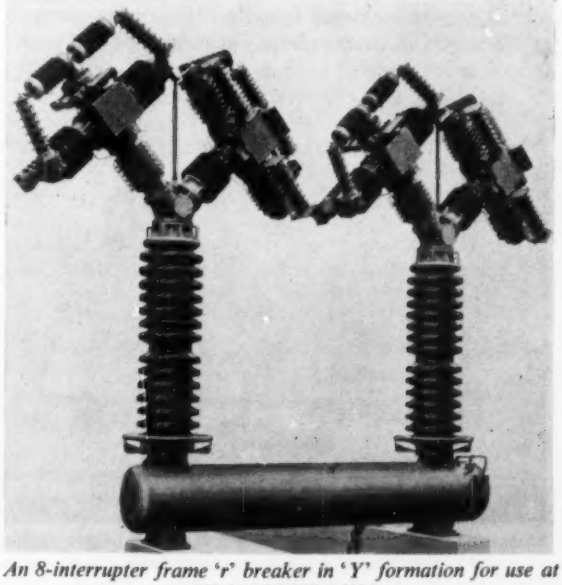
The present methods of proving extra-high-voltage multi-gap circuit-breakers are based on unit testing of at least one interrupter at 100 per cent of its share of voltage at full short-circuit current. The output of the plant can therefore be decisive in dictating the number of interrupters to be employed in a large breaker at extra-high-voltage.

To prove satisfactorily breaker ratings up to 50 000 MVA at 500 kV and above, and at the same time to keep the number of interrupters to the required minimum, it has been necessary to increase the capacity of the plant at the Nelson High Power Laboratory.

The existing plant consists of two 3 000 rev/min alternators with associated transformers and ancillary equipment. To increase this capacity, two new alternators are being installed together with associated transformer banks and full ancillary equipment, with a capacity to test at voltages up to 600 kV.

There are several new features in the plant design. These include the provision of servo control for the synchronisation of four machines, and the installation throughout of pressure-immersed 'make' switches, which give close control of point-on-wave voltage application and negligible pre-arcing. Each switch has a making capacity rating of 300 kA peak.

The provision of extra plant has more than doubled the output of the existing equipment, which was itself doubled in 1947. If the present trend in the increase of circuit-breaker ratings is maintained, then a form of synthetic testing, acceptable to users, may well be the only economic means available for proving circuit-breaker performance.



An 8-interrupter frame 'r' breaker in 'Y' formation for use at 400 kV 25 000 MVA

Longest 400 kV Link for the Super-grid

THE erection and installation of the 400 kV overhead power link spanning the River Thames between West Thurrock, Essex, and Swanscombe, Kent, adds another chapter to the story of the supergrid. The contract for the crossing was awarded to British Insulated Callender's Construction Co Ltd by the Central Electricity Generating Board early in 1959, and provides a vital extension of the existing supergrid north of the Thames, through the C E G B's new 1 000 MW steam generating station at West Thurrock, connecting new lines to Canterbury, Lydd, the cross-Channel link and the nuclear power station now under construction at Dungeness. The double-circuit link incorporates six steel-cored aluminium conductors and a similar earth wire. These are the largest of their kind ever used on an overhead power transmission line forming part of the British supergrid.

The main factors influencing the design and height of the two crossing towers and the two anchor towers were the 4 500 feet (1 372 m) length of the main span and a Port of London Authority requirement of a minimum clearance of 250 feet (76 m) between the lowest point of the conductors in the span and mean high water level, while the survey associated with the setting out of the towers called for a great degree of accuracy. The four towers are aligned to within 0·25 inch (6·35 mm) over the route length of 7 700 feet (2 347 m), and the distances between them measured to within 3 inches (76 mm).

To assist in the alignment, neon tubes were mounted vertically on short masts at each site and sighted by night-time theodolites under VHF radio control. VHF radio control was maintained during the complete operation on site.

Work on the foundations, which were subject to a separate contract, began in early 1959, and construction of the towers themselves began in August of that year.

Linesmen remove the holding rope attached to the leading dead-end hauling tail in front of the south anchor tower of the overhead power link across the River Thames

Tower Erection

The two 630 feet (198 m) suspension towers are constructed mainly of high tensile steel and weigh approximately 436 tons (443 000 kg) each. The two anchor towers which are set back 1 600 feet (488 m) from the suspension towers are 145 feet (44 m) high and weigh 99 tons (106 000 kg) each.

Due to the nature of the ground it was necessary to sink 30 reinforced concrete piles under each leg of the two crossing towers. On the north bank these piles were driven to a depth of 40 feet (12 m) and to 45 feet (13·7 m) on the south bank. At each of the anchor towers, 99 piles were required to provide resistance to the overturning forces created by the pull of the conductors and earth wire.

The crossing towers are tapered in outline. They are 100 feet (30·5 m) wide at the base and 10 feet wide (3 m) at the top. A cruciform arrangement was adopted for each main leg. Several unusual features of design have been incorporated. Permanent working platforms are provided to facilitate maintenance and conductor erection, and the maintenance crossarms at the tops of the towers overhang the conductor crossarms by 10 feet (3 m).

A 15-foot (4·6 m) square central column, which carries the stairways to the 375-foot (114 m) level, is hollow and designed for raising within the body of the tower replacement parts and equipment required for maintenance purposes. The advantage of being able to do this, on towers with wide bases where a straight lift from ground level on the outside is not possible, will be quickly realised. Permanent winches are provided on the 375-foot (114 m) and 559-foot (170 m) platforms to raise and lower components.

The anchor towers are vertically faced on the front side, with a sloping face at the back. Working platforms are again a permanent feature of these structures and auxiliary crossarms are provided to carry the jumper connections from the crossing spans to the connecting transmission lines.

Construction of each crossing tower began with the erection of 125 feet (38 m) of the central column, upon which was mounted an 80-feet (24 m) derrick in luffing rig. This derrick was used to erect the first 62·5 feet (19 m) panel of the tower. When this was completed a further 62·5 feet (19 m) of the central column was built and the luffing derrick raised for the erection of the second tower panel. This was repeated until the maintenance platform was reached at 375 feet (114 m), after which the derrick was 'floated' on steel wire ropes secured to the corner legs of the towers and used in this way for the remainder of the construction. Two winches were used on each tower for raising all men and materials, and a lifting speed of 40 to 50 feet (12 to 15 m) a minute could be achieved. A foot-operated form of 'dead man's handle' was employed to apply the safety

brakes and to guard against mishap should the winch operator suddenly become incapacitated during haulage. For the erection of the top maintenance crossarm, an additional derrick was employed. The crossarm was erected section by section and when completed was used to raise the suspension insulator crossarms from ground level, where they had been previously assembled.

The Conductors

The steel-cored aluminium conductors used for the crossing were designed in collaboration with the C E G B by the Wire Mill Division, Prescot, Lancs, of British Insulated Callender's Cables Ltd, who were responsible for their manufacture. Considerable assistance was afforded by Rylands Brothers Ltd, Warrington, who collaborated in the actual manufacture. The conductors, designed for 400 kV transmission, consist of 90/0·123-inch (3·1 mm) diameter preformed galvanized steel wires of 120-ton (121 926 kg) quality and a centre wire of 0·132-inch (3·35 mm) diameter. This steel core is surrounded by 74/0·133-inch (3·378 mm) aluminium wires in two layers and a layer of 36/·0266 square inch (17·2 mm^2) (·160 inch (4·064 mm) deep) wedge segmental aluminium wires. The latter are applied to present a smooth outer surface to reduce aerodynamic effect over the large spans. The overall diameter of the completed conductor is approximately 2·214 inches (56 mm) and nine lengths are being supplied, giving two spares.

The unstressed length of each conductor, measured between the centre lines of dead-end eyes at 60 deg F (15·6 deg C) is 7 754 feet (2 363 m) plus or minus one foot (305 mm). Accurate measurement to determine the length to be manufactured was achieved by setting up a $\frac{3}{8}$-inch (9·5 mm) diameter steel conduit over an Ordnance Survey checked base line 230 feet long (70 m). The tube was used to eliminate sag and ensure maximum straightness of the centre steel wire, which was drawn through and marked. Corrections were made for variations in temperature and tension. Because of the nature of the crossing, the compression dead ends were fitted to the conductor in the factory. The conductors, each weighing 21·5 tons (21 840 kg), were delivered to the West Thurrock site on drums with a diameter of 12 feet 10 inches (3·9 m) and a width of 6 feet 5 inches (2 m). The gross weight of each conductor and drum was 26 tons (26 417 kg).

Conductor Accessories

Specially designed Noral conductor accessories—including armour rods, corona-bells, and dead-end terminations—were developed by Alcan Industries Ltd.

The 6 feet long dead-end fittings are similar to the usual 'Noralgrip' type, consisting of a steel forging to hold the steel core, and an aluminium sleeve to carry the current and also take some of the load.

The dead-end fittings were subjected to type tests which were carried out at the National Coal Board's laboratories at Bretby, near Burton on Trent. The British Standard for dead-ends to suit the conductor used requires a loading test of 123·5 tons (125 482 kg) maximum, reducing to 117 tons (118 877 kg) which is then held for one minute. On a test to destruction a terminated conductor broke at 126 tons (128 022 kg), showing that these new fittings are well within the safety limits required for the crossing.

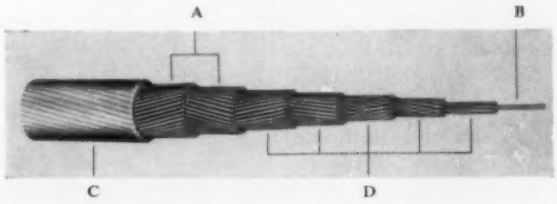
Stringing the Conductors and the Earth Wire

The stringing of the six conductors and the similar earth wire across the 4 500-foot (1 370 m) main span and the 1 600-foot (488 m) anchor spans for the crossing posed a number of problems. Of these, the most notable were weight and length—each conductor weighs 21·5 tons (21 840 kg) and is 7 754 feet long (2 363 m)—and the condition in the contract which required that no conductor should touch land or water at any stage, owing to the possibility of damage by corrosion or abrasion. Such damage could give rise to corona losses and television reception interference. The attachment of clamps and haulage devices to the conductors during erection was also prohibited for similar reasons. In view of these considerations an overhead track rope with a special suspension trolley system was used for erection.

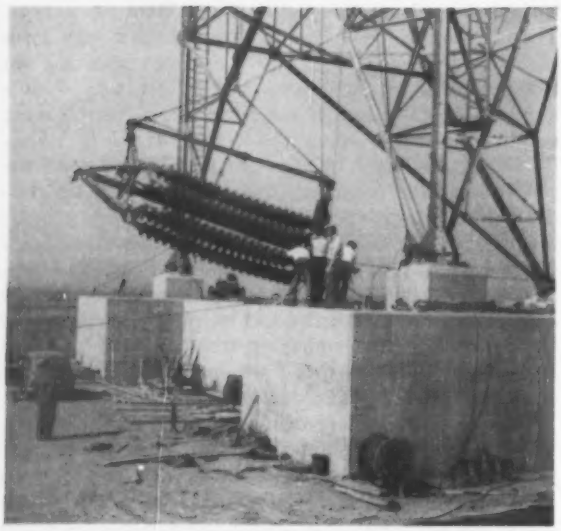
Because of the nature of the crossing, and the heavy tensions involved, compression type dead-end clamps were fitted to the conductors in the factory. This required accurate measurement of the conductor prior to fitting and a tolerance of plus or minus 12 inches (305 mm) on the unstressed lengths of 7 754 feet (2 363 m) was worked to in manufacture by the B I C C Wire Mill Division.

At a time agreed with the Port of London Authority, the river was closed to allow the track and haulage ropes, previously laid in the river, to be winched up between the crossing towers. The period of closure permitted was four hours. A similar closure was required to dismantle the two ropes.

For the stringing operation, a $1\frac{1}{4}$-inch (31·75 mm) diameter fully-locked coil aerial track rope was installed over carriages at the tops of all four towers and connected through tensioning tackles to the ground behind each anchor tower. Alongside and slightly above was installed a double length of $\frac{9}{16}$-inch (14·288 mm) diameter steel haulage rope connected to suitable winches sited at the backs of the anchor towers. Each conductor was laid in small rubber-lined bobbins attached to the end of 10-foot (3 m) long vertical booms suspended from twin wheeled carriages running on the track rope and clamped to the haulage rope and was then pulled across the system under light tension. These suspenders were fed on at 80-foot (24 m) intervals and had to be removed at each crossing tower and replaced in the adjacent span. To carry the conductors themselves through the crossing towers, and to facilitate lowering them to their final position, a conductor cradle with two 5-foot (1·5 m)



The steel-cored aluminium conductor used on the Thames crossing showing (A) 74/0·133 inch (3·378 mm) aluminium wires in two layers, (B) the centre wire of 0·132 inch (3·353 mm) diameter, (C) one layer of 36/0,066 in^2 (14·58 mm) wedge segmental aluminium wires, and (D) 90/0·123 inch (3·124 mm) preformed galvanised steel wires of 120 ton (121 926 kg) quality



The tension insulator assembly at the north anchor tower slung ready for lifting into position

diameter rubber-lined sheaves at 26-foot (7·9 m) centres was hung from the top of the crossing towers just below the track rope.

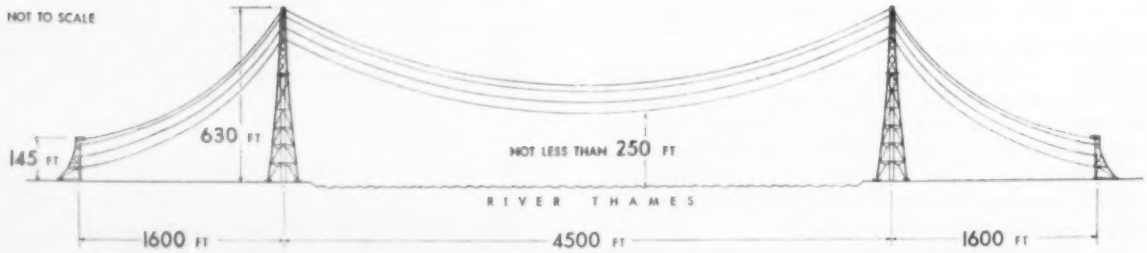
As the leading end of each conductor reached the far anchor tower, tension was applied at both ends to lift it clear of the suspenders. It was then lowered, by means of the cradle at the crossing towers and by bridled tackles down the faces of the anchor towers, to its final position when it was sagged. Tension insulator assemblies each weighing 3¼ tons (3 293 kg) with a length of 24½ feet (7·5 m) and comprising 8 strings of 20 × 12¾-inch diameter porcelain units in parallel were introduced and landed on the anchor towers—six on each. Armour rods were fitted to each conductor which was then placed in a saddle and attached to the crossing tower suspension insulator assembly. Each assembly comprises 6 strings of 20 × 14-inch (36 cm) diameter porcelain units in parallel, weighs nearly three tons and is 21½ feet (6·55 m) in length. Some indication of the magnitude of the tensioning operaton is given by the fact that the erection tensions involved were of the order of 30 to 35 tons (30 481 to 35 562 kg) per conductor.

After installing each conductor the suspenders were returned to their starting points in preparation for the next conductor of the same circuit. The conductors in each circuit were erected in the order of bottom, middle, top. After the stringing of the first circuit the track and haulage ropes were transferred to a similar position at the top of the towers above the second circuit. When this was completed the track and haulage equipment was moved to the centre of the towers for the erection of the earth wire.

When the first conductor was run out, the time taken amounted to nearly two and a half days, but this was subsequently improved upon to less than one day for later conductors. Under favourable conditions speeds of up to 25 to 30 feet (7·6 to 9 m) per minute were achieved. Allowing for the time to set up and prepare the conductor drum, run the conductor, lower it to its final position, tension and sag, install tension and suspension insulator assemblies, and return the suspenders to the starting point, stringing was completed at the rate of about one week per conductor. On a project of this nature, weather conditions have a considerable influence on progress.

All operations were directed by VHF radio control and there were as many as six radio sets maintaining contact between teams on the ground and at the tower tops on both sides of the river.

The main contractor was British Insulated Callender's Construction Co Ltd. The towers were designed by Blaw Knox Ltd and fabricated by Painter Bros Ltd, Horseley Bridge and Thames Pigott. The insulators were manufactured by Bullers Ltd and the dead-end assemblies and armour rods by Alcan Industries Ltd.



The diagram (not to scale) shows the position of the anchor and suspension towers for the Thames crossing. The 400 kV overhead line is the first one to use this voltage in the U K, and provides a vital link to the existing supergrid that will also feed the cross-Channel cable. The conductors are the largest of their kind ever used in the British overhead transmission system. The crossing towers are 630 feet (198 m) high, and the anchor towers 145 feet (44 m) in height, the distance between the anchor towers and the suspension towers being 1 600 feet (488 m) and the actual span across the river is 4 500 feet (1 372 m). The height between the lowest conductor and mean high water level is 250 feet (76 m)

Progress in Motor Design

A NEW 'INTERNATIONAL' RANGE

IN an article[1] in THE BEAMA JOURNAL of February, 1960, the author traced the development of a c motor design in the U K with particular reference to British and American standards. Experts in a number of countries have stressed the desirability of surmounting national differences, but with the wide variety of requirements and applications, the establishment of standards and the production of a 'universal' range of motors is no easy matter.

This article, which is to some extent complementary to the article referred to above, reviews the present position in relation to British (B S), American (N E M A) and German (D I N) standards, and describes a new range of motors recently introduced by Lancashire Dynamo and Crypto Ltd which are dimensionally to BS 2960 Part II, but which also comply with N E M A and D I N standards and international recommendations.

First N E M A Standards

The first dimensional standards to become established in practice were those of the National Electrical Manufacturers' Association of America (N E M A). The association's recommendations have been increasingly adopted in the United States.

The N E M A specifications are now far-reaching: they cover ratings, enclosures, dimensions, applications and performance of a c and d c electric motors and generators from fractional sizes to horsepowers of 1 000 and more.

The N E M A specifications established fixing dimensions for standard foot-mounting and flange-fixing machines and introduced preferred horsepower ratings. These ratings, at first sight, appear not unreasonable, but closer examination will reveal that the incremental increases are not consistent, varying from 20 per cent (as, for instance, in the case of 50 to 60 h p) to 67 per cent (in the case of 3 to 5 h p). This is reflected in the fact that some frame sizes are omitted from the table of horsepower assignments whereas others are duplicated.

The original standard catered for Class A insulation (50 deg C rise for ventilated motors and 55 deg C rise for totally-enclosed motors) as well as for service factors and overload capacity. The resulting dimensions were generous.

It was not until 1954 that the first range of standardised dimensions was introduced in the United Kingdom. These dimensions were for motors of the totally-enclosed fan-cooled type from 1 to 25 h p, these being chosen because of the growing demand for them.

The dimensions—laid down in BS 2083—were made identical with those in the N E M A range, with Class A insulation (55 deg C rise) and continuous maximum rating with no sustained overload. Based on more up-to-date techniques, outputs higher than those specified by N E M A were established.

Following the publication of this British Standard, N E M A revised its own standards both for ventilated and for totally-enclosed fan-cooled motors, introducing many new frame sizes and superseding others, thereby permitting most assigned horsepower ratings to be increased above those set in the British standard.

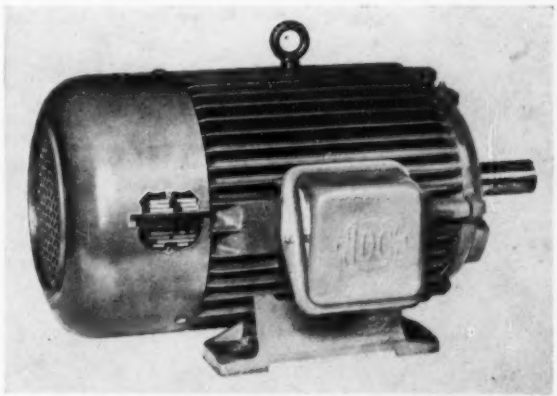
I E C Recommendations

The next stage came with an effort by the International Electro-Technical Commission (I E C) to secure dimensional standardisation on international lines. The large number of countries represented on the Commission, all of them with views of their own, as well as the Commission's inability to meet with any frequency, made agreement difficult to reach. Nor were matters made any better by the incompatibility of inch and metric dimensions. Nevertheless—and to its considerable credit—the Commission succeeded in establishing a range of dimensions which were ultimately published in 1960 in the form of a recommendation.[2]

Dimensions were based on the current N E M A frame sizes with three lengths per diameter, although most national standards utilise only two. Two sets of dimensions were established, in inches and millimetres, which correspond fairly closely.

Assignment of horsepower ratings, so closely governed by performance requirements, has not been realised by the I E C. The shaft dimensions recommended are allied to the torque transmitted rather than to frame size, which applies also to the flange dimensions of flange-fixing machines.

In 1958 the British Standards Institution issued a specification (BS 2960) for a range of ventilated motors from 1 to 50 h p. Dimensions were to the N E M A specification and subsequently proved to be compatible also with I E C requirements. Performance was in accordance



One of the motors from the new Lancashire Dynamo range

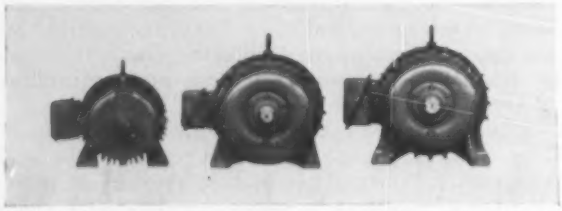
with BS 2613, with Class E insulation and corresponding temperature rise of 65 deg C. The outputs established were one step higher than the corresponding N E M A motors.

In 1961 the British Standard for totally-enclosed fan-cooled motors was revised. Using Class E insulation, it was found possible to obtain outputs equal to those of the corresponding ventilated types, which at that time was regarded as quite an achievement. This revision was issued as BS 2960 Part II.

D I N Standards

Almost in parallel with this British development, the standards institution of West Germany—Deutsche Industrie Normen (D I N)—in common with other European countries, came forward with a range of totally-enclosed fan-cooled motors conforming with I E C proposals and thus very similar to the British and American sizes. Outputs, however, were higher than those laid down by the B S I.

At the present time, it is understood, D I N is considering proposals for ventilated motors with outputs even greater than the corresponding totally-enclosed fan-cooled machines. These proposals, however, are unlikely to reach fruition for some months.



This shows the progressive reduction in frame sizes for the same speed and h p rating. On the left is one of the new EDL series; next is a type D to BS 2960 (II); on the right is a type B to BS 2083

Since the D I N proposals became known before the issue of BS 2960 Part II, the B S I wisely inserted a clause in the foreword to its specification, reading as follows:

> 'The assignment of horsepower ratings is made in accordance with British practice at the present time, but designs and manufacturing techniques both in this country and abroad are under continual review. As soon as techniques have advanced sufficiently to enable increased assignments of horsepower ratings to be made, a corresponding change in the standard will be considered. Particular effort will be made to achieve and preserve alignment with the recommendations of the International Electro-Technical Commission and with the standards of other countries'.

Meanwhile, it has been suggested that N E M A may shortly revise its standards in respect of horsepower assignments, class of insulation, temperature rise and performance. There is no firm information about this at the moment, but there is little doubt that the American manufacturers are pressing for action on these lines.

All this may seem confused and unsettling to the users of electric motors. But it should be borne in mind that standards must be revised from time to time to keep pace with new materials and advanced techniques which are continually coming forward.

A New 'Compatible' Range

More so than many other manufacturers, Lancashire Dynamo and Crypto Limited has had to contend with this ever-changing situation, first because of its close connection with Canada, whose standards are similar to those of N E M A, and, second, because of the company's long-established policy of producing motors to special electrical and mechanical requirements.

Moreover, it is realised that Britian must be in a position to offer motors having outputs at least equal to those produced in Europe to the D I N specification. Accordingly, after some months of research and development, the company has now announced a range of totally-enclosed 'Fankuld' motors (named E D L) which enables outputs to be obtained higher than those specified in BS 2960 Part II and equal to those of D I N; in some cases, outputs even better than those of D I N are obtainable.

By the judicious use of basic common parts, motors can be built to comply with the requirements of different national standards and with the performances laid down in the United Kingdom (BS 2613), in Germany (VDE 0530) and in the United States (N E M A). This is shown in the following table:

LDC type number	*Dimensions*	*Outputs*	*Performance*	*Temperature rise*
EDL	BS 2960 (II)	Higher than BS 2960 (II)	BS 2613	65°C
ED	BS 2960 (II)	BS 2960 (II)	BS 2613	65°C
EDB	BS 2083	BS 2083	BS 2613	55°C
EDM	DIN 42637	DIN 42637 (or better)	VDE 0530*	75°C
EDN	NEMA	NEMA	NEMA	55°C
EDA	NEMA	NEMA (but 50 c/s)	BS 2613	55°C
EDS	BS 2960 (II)	BS 2960 (II)	BS 2613	55°C

Temperature rise measured by thermometer except * measured by resistance, as specified in VDE 0530.

References

[1] Hill, C. V., *Electric Motor Development and the User*, THE BEAMA JOURNAL, **67**, No 1, pp 22-26

[2] I E C Publications, Nos 72/1 and 72/2

Notes

Successful Operation of Nimrod Injector

On August 1, 1961, the first proton beam accelerated to the design energy of 15 million electron volts (15 MeV) was obtained from the linear accelerator injector which forms the first stage of NIMROD, the 7 000 MeV proton synchrotron under construction at the Rutherford High Energy Laboratory of the National Institute for Research in Nuclear Science, Harwell. Commissioning of the injector began on July 1, 1961.

The linear accelerator consists of a cylindrical copper cavity approximately 44 feet (13·7 m) long and 5½ feet (168 cm) in diameter, with 48 tubular electrodes known as drift tubes spaced along its axis, the whole being enclosed in a vacuum envelope. Approximately 1 MW of r f power is supplied to the cavity at its resonant frequency of 115 Mc/s to set up the required accelerating fields across the gaps between drift tubes. These drift tubes are necessary to screen the protons from the field when its direction reverses every alternate half-cycle, and they also contain focussing magnets which constrain the protons to form a proper beam close to the machine axis. The drift tubes increase in length along the tank to correspond with the increase in proton velocity. Protons enter the linear accelerator with an initial energy of 0·6 MeV from a pre-injection stage which is basically a conventional d c accelerator.

Pulsed 15 MeV beams will be delivered by the injector to the synchrotron at rates up to two per second and at pulse lengths up to two milliseconds. Within the synchrotron, they will be constrained to a circular path by a suitably varying magnetic field. In this way they will make many revolutions, receiving a small acceleration at a particular point in the orbit until the output energy of 7 000 MeV is reached. The protons will then be directed to suitable targets for experiments in high energy nuclear physics.

Construction work on NIMROD started in August 1957 and is expected to be completed during 1962.

Crane Controls for Amsterdam

Metal Industries (Europe) S.A., a company in the Metal Industries Group, has secured an order, through its office in The Hague, for the complete electrical equipment of eight harbour cranes for the Amsterdam Harbour Board.

The contract, which is valued at nearly £50 000, calls for the supply of automatic control panels, motors and installation.

The control panels will be manufactured by Brookhirst Igranic at Bedford and the motors by Lancashire Dynamo & Crypto Ltd at Trafford Park.

The Amsterdam Harbour Board has already installed a large number of cranes equipped with Brookhirst Igranic controls. These cranes replaced those destroyed during the Second World War.

Further Indian Railway Contract

British Insulated Callender's Cables Limited announce that they have been awarded a £1 million contract from the Indian Railway Board for the supply of overhead equipment for 25 kV 50 c/s a c railway electrification over 250 track miles (400 km) of suburban railway in the Calcutta area. With this latest contract, the third of its type which B I C C have received from the same source since December 1958, the Group will have been responsible for nearly 1 000 track miles (1 610 km) of 25 kV 50 c/s a c electrification in India at a cost of some £4 700 000.

The first contract, announced in December 1958, was for the electrification of a 400 mile (644 km) section near Calcutta of the main line between Calcutta and Bombay on the South Eastern Railway. This section, between Tatanagar and Rourkela, with a branch from Rajkharswan to Dongoaposi, links the iron ore fields in Bihar with steel plants at Tatanagar and Rourkela. Very rapid progress has been made on this contract, which was the first to be awarded in India for high voltage a c operation. A trial section was put into operation 12 months from the date of order, and the major portion of the scheme is already in commission.

Under the second contract awarded to the B I C C Group, which was announced in June 1960, some 300 miles (483 km) of the Eastern Railway system between Delhi and Calcutta are being electrified. This section lies between Gaya and Moghalsarai, and includes the largest marshalling yards in Asia. Both this contract and the previous one were for freight service and intended primarily to provide the rail link that is essential for India's expanding steel programme. The new contract will facilitate the carriage of both freight and passengers to and from the developing suburban areas of Calcutta, particularly those to the North and North-East. South of the city, Sealdah station, which is embraced within the overhead electrification scheme, will eventually be able to handle a greatly increased volume of rail traffic. Sealdah is said to be one of the world's busiest major terminals still being operated by steam traction.

These three orders, taken in conjunction, represent an important contribution by the B I C C Group towards the implementation of the Indian Railway Board's decision to standardise the country's electric traction systems. The latest contract, when complete, will constitute the first suburban railway section in India to be equipped for overhead high voltage a c operation. For all three contracts, a small number of specialist traction engineers from B I C C Construction Company is responsible for the work and for training and supervising a large force of local engineers and field personnel.

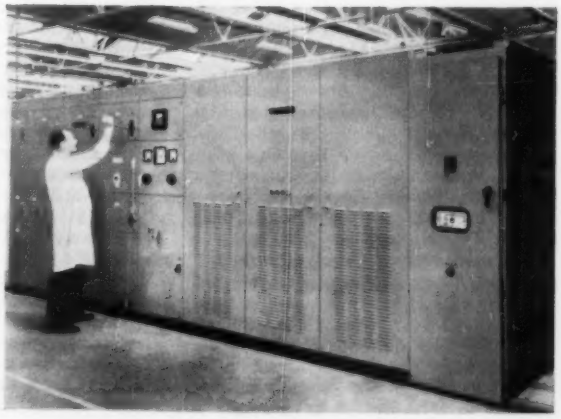
Power Manipulators for Denmark and Switzerland

G E C (Engineering) Ltd has received two orders for remote handling equipment, one from the Danish Atomic Energy Commission worth £16 454 and the other from the Swiss Federal Office of Works valued at £23 844. Both orders include a standard G E C Mark I power manipulator with a lifting capacity of 750 lb (340 kg) and a 1½ ton (1 525 kg) hoist unit. The Danish equipment will be installed in new hot cells now under construction at the research establishment at Riso near Copenhagen. In addition to the manipulator and hoist unit, two cable take-up units have also been supplied by G E C.

As part of the Swiss contract G E C is also supplying a special hoist unit fitted with a movable frame designed to carry a remotely-controlled television camera supplied by Pye T V Ltd. This viewing equipment and the remote handling equipment is for the new hot cells at the research station of the Eidg. Institut für Reaktorforschung at Würenlingen, near Zurich.

The power manipulator, which is to be fitted with an anti-collision ring, and the ordinary hoist unit, will be installed in a normal hot cell suite, but the special hoist unit with its television camera will operate in a windowless cave. The camera controls, which include pan and tilt motions, will be built into a special cubicle together with the monitor screen and the normal hoist unit controls and indicator lamps.

The main features of the G E C Mark I power manipulator are that a minimum of space above the rails is required and that a c squirrel-cage motors are used for the in-cell equipment. Each manipulator is to be fitted with a mechanical hand having an open distance of 5 in (127 mm).



An indoor 'packaged' substation manufactured by The English Electric Co Ltd for use in a large jute mill in Jamaica. The 4 000 V air circuit-breaker, the main 1 000 kVA 4 000/440 V dry type transformer, together with the 1 600 A air circuit-breaker and the outgoing feeder section, are all housed in one compact unit

Special Computer Division Formed

The formation of a Special Computer Division within the Data Processing Group of Divisons of Elliott Brothers (London) Limited is announced in a statement by Elliott-Automation Limited.

The new Division specialises in tackling the problems associated with the 'on-line' application of digital computers to continuous operations. No great amount of work has yet been done in this field anywhere in the world, with the result that there are many fundamental studies to be carried out in developing the new techniques required.

Not the least of the problems is that there may be a wide range of sources of information, such as radar signals, relayed radio messages, teleprinters and instruments of many kinds in addition to manual keyboards all feeding data to a computer simultaneously while at the same time it is providing outputs in the form of visual displays, command signals and the automatic logging of data. The complexity of such systems is very great and has given rise to the need for the formation of special teams of experts to study them.

The Division is at present engaged upon the development of an experimental Air Traffic Control System, an advanced airline seat reservation system and the control and switching of telegraph communications networks.

Flourmilling Contract from the Philippines

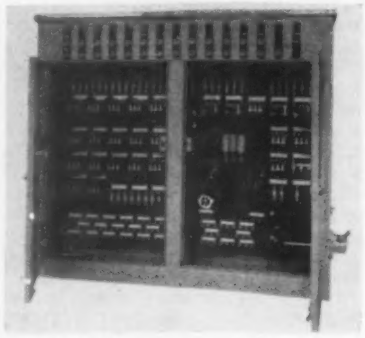
For a new flour mill contract valued at almost 1¼ million dollars received from the Philippines by Thomas Robinson & Son Ltd, of Rochdale—the fourth large contract that Robinsons have received from the Philippines since the Republic established its own flourmilling industry in 1958—electric motor control gear will be manufactured in Brighton by Allen West & Co Ltd.

The largest of ten Allen West multi-motor control panels ordered for various milling operations is a 25-motor panel. It will be located on the second floor and will control agitators, offal blowers, bleachers, worm conveyors etc.

On the mill third floor a 19-motor panel will control purifiers and plansifters, and on the fourth floor will be a 14-motor control panel for valves. In the screenroom there will be an 18-motor panel for blowers, conditioning and washing plants, screens and feeders, as well as four other multi-motor panels controlling other processes. The warehouse will have a nine-motor panel for blowers and valves, and there is also to be a four-motor panel of machine tool pattern for other duties.

The rollermill floor will have four Allen West control desks each incorporating a process timer arranged to give a starting pulse to each of 23 motor starters at intervals of three seconds.

Rollermills will be pushbutton controlled, either individually or in groups. Seventy-two Allen West 'SC2N' main direct-on starters, in single and back-to-back arrangements, will be mounted on floor stands specially designed to fit in with the motor arrangements on the mill floor. A start/stop unit adjacent to each half of every rollermill



One of the 25-motor panels forming part of the electric motor control gear manufactured by Allen West & Co Ltd for a large flour mill in the Philippines

enables the operator to isolate that pair of rolls from the main panel.

In all, 100 individual Allen West starters have been ordered for the new mill. It is to be built for the Central Philippine Milling Corporation and will be sited at Iligan, near Cebu City. It will have a capacity of 240 tons (243 851 kg) per 24 hours, and pneumatic conveying will be used throughout. All the machinery will be manufactured in Rochdale, Lancashire.

Electrical Equipment for Polish Trawlers

An order valued at over £100 000 for the supply of electrical equipment for 13 stern trawlers to be built in Poland has been obtained by Laurence, Scott & Electromotors Ltd, the electrical engineers of Norwich and Manchester.

The equipment for each vessel includes one 240 kW and one 120 kW variable-speed shaft-driven generators, one 300 h p trawl winch motor, two 120 kW diesel-engine driven auxiliary generators and all the associated control gear. The two shaft-driven generators will be coupled through reduction gearing to the main propulsion engines, which are to be manufactured by Mirrlees, Bickerton and Day Ltd, of Stockport.

The order follows a number of visits to Poland by the company's marine sales manager for the discussion of technical and commercial details.

Tanganyika's Largest Hydro Scheme

Equipment for Tanganyika's largest hydro-electric station has been ordered from The English Electric Co Ltd by Tanganyika Electric Supply Company. The equipment, consisting of two 14 700 h p vertical Francis turbines and valves together with two 10·5 MW generators and associated gear, will be made at the Company's Netherton works, near Liverpool. The value of the contract is some £300 000.

It will be installed in an underground power station on the River Pangani some 40 miles (64 km) from the port of Tanga. Known as the Hale Scheme, it should go into operation early in 1964.

The power generated will be fed into the existing Tanga system and transmitted by 132 kV transmission lines to Dar-es-Salaam and the Central Line areas.

In addition English Electric has already received an order for 33 kV substation switchgear, valued at some £30 000, which will be used in the transmission network. This equipment will be made at Stafford.

The cost of the total scheme is approximately £5 million, of which the Tanganyika Government is advancing to the Electric Supply Company £1 750 000 and the Colonial Development Corporation £3 million, both loans being secured by a debenture.

£6 million Egyptian Power Station Order

A £6 million comprehensive contract for a 120 MW extension to the Cairo South Power Station has been awarded to English Electric Co Ltd by Cairo Electricity and Gas Administration.

This order, one of the largest for British industry in the Middle East since 1957, was gained in the face of intense competition. The existing generating plant is of Continental manufacture. The first call for tenders was in June, 1960, and the specification covered boilers, turbo-alternators and auxiliary equipment. The power station, when finished, will be one of the biggest in the Middle East. Part of the payment will be in cotton, arranged in conjunction with the international firm of cotton merchants Louis Dreyfus & Co Ltd.

Although English Electric are the main contractors and will co-ordinate the complete project, it is an Anglo-Egyptian enterprise in that Misr Concrete of Cairo have a £750 000 contract for the civil engineering work. The plant will be in operation early in 1964.

The order covers the complete electrical and mechanical equipment to supply a further 120 MW for domestic and industrial use in the city.

The two 60 MW steam turbines will be made at the Rugby works of English Electric, the alternators, transformers (including two rated at 75 MVA) and 63 kV switchgear at Stafford, and the low voltage switchgear and fusegear at Liverpool.

The four boilers, each of 441 000 lb (200 000 kg) per hour capacity, will be manfactured by Simon-Carves Ltd of Stockport.

Since the second world war English Electric have installed the complete electrical generating equipment for the Port Fouad power station, and supplied locomotives to the Egyptian State Railways valued at about £4½ million.

Turbogenerators for Australia

Turbogenerators and associated plant worth over £1 million sterling are to be supplied to Australia by C. A. Parsons & Co Ltd, Newcastle upon Tyne.

The State Electricity Commission of Western Australia has ordered from Parsons two 60 MW steam turbo-generator sets together with condensing and feed heating plant, for installation in the new Muja generating station. The station is situated on an open-cast coal field near Collie and not far from Bunbury power station where four 30 MW turbo-generators of Parsons manufacture are now running.

These new sets will run at 3 000 rev/min and incorporate turbines of the two cylinder design. They will operate with steam conditions of 900 lb/in² (63·3 kg/cm²) pressure and 900 deg F (482 deg C) temperature.

The generators are rated at 60 MW, 0·8 power factor and will operate at 11·8 kV; they will be cooled by hydrogen.

All the condensing and feed heating plant will be manufactured at Parsons Whyalla works, South Australia.

Mexican Order for Diesel Alternators

An order worth over £330 000 for diesel-alternator sets for the Commission Federal de Electricidad of Mexico has just been received by the Diesel Engine Division of the English Electric Co Ltd.

The equipment to be supplied consists of ten completely self-contained mobile generating stations, which are to operate in temperatures varying between 77 deg F (25 deg C) and 113 deg F (45 deg C) and at altitudes between sea level and 7 220 feet (2 200 m). They will be used as local sources of power.

Delivery of the stations starts in five months. Some of the engines may be arranged to run as dual-fuel units, using natural gas. The whole project will be engineered and controlled by the company's Diesel Engine Division which is based at Brownsover Hall, Rugby.

The main engine castings will be cast in the Rugby works foundry and the engines will be built and tested at Preston. The alternators will be made at Bradford and the switchgear at Liverpool. The complete stations will be assembled at Preston.

Each station consists of a road trailer upon which is mounted a 12-cylinder, exhaust turbo-charged, charge air cooled, vee form diesel engine, designed to develop 1 356 b h p when operating in any conditions between the limits given above. The engine will be directly coupled to a 1 205 kVA, 964 kW alternator, which will generate at 2 400 V at 720 rev/min.

The engine and alternator are mounted on a fabricated steel underbed, and anti-vibration mountings will be inserted between the underbed and the road trailer.

Cooling of the engine will be by means of an air blast radiator, and as starting is by compressed air the necessary engine-driven compressor and air receiver are mounted on the trailer. The alternator and exciter switch panels will be of the OLX oil-break type.

New Permali Factory for India

Final arrangements have now been made for the setting up of a £127 000 Permali factory in India to manufacture a full range of densified wood laminates. The operating company will be styled Permali-Wallace Ltd and its location is Bhopal, about 400 miles (644 km) south of Delhi.

This new company is the outcome of collaboration between Permali Ltd of Gloucester and Chas. Lowe & Co Ltd of Manchester with the Indian Plywood Manufacturing Co Ltd and The Wallace Flour Mills Co Ltd of Bombay, India.

Permali, Hydulignum, Jabroc and Permawood are the specialised wood laminates to be made. These have varying degrees of impregnation and density to suit their established applications as electrical insulation, rail track insulation, textile machinery parts, neutron shielding etc. It is expected that this manufacture will considerably benefit the Indian foreign exchange position.

The erection of the first of two 40 MVA synchronous condensers at a substation in Iver, Buckinghamshire. The machine, manufactured by Associated Electrical Industries Ltd, is the first of its type to be installed in the U K, although A E I have supplied similar machines for use in Australia, Africa, India, New Zealand and Spain

Construction of the factory buildings is scheduled to begin in November this year and the whole installation completed by the late summer of 1962. The initial annual turnover is estimated at £250 000. Full manufacturing facilities are being incorporated and include a press shop, machine shop and finishing departments. A special feature of the factory is the provision of humidity control equipment in the processing areas to overcome the extremes of the Indian climate. The special purpose process plant and most of the machine tools are being sent from Britain.

Indian sources will be used almost entirely for the raw materials, the special resins required being manufactured on the premises by Permali-Wallace Ltd and combined with suitable indigenous timbers.

The new factory will be staffed entirely by Indians and some of the key personnel will first receive special training in the U K.

Radio Equipment for Canada and Peru

The General Electric Co Ltd of England is to supply via Canadian General Electric Co the radio and multiplexing equipments for a broadband radio link between Moncton in New Brunswick and Gore in Nova Scotia, Canada. The link will consist of two terminal and two repeater stations and will carry two both-way S H F radio channels operating in the 6 000 Mc/s frequency band. It will form part of the Canadian East Coast microwave network being developed by The New Brunswick Telephone Co and the Maritime Telegraph and Telephone Co.

The equipment will convey either a television circuit or 960 speech circuits on each radio channel and will link up with other G E C equipments in the network operating in the 2 000 Mc/s band.

The General Electric Co Ltd have also been awarded the 3 million dollar contract by the Compania Nacional de Telefonos del Peru to supply the radio and multiplexing equipment for a microwave network linking the towns of Arequipa, Lima, Trujillo, Chiclayo and Piura in Peru.

The network comprising ten terminal and 54 both-way repeater equipments will be the longest in South America, extending for 1 100 miles (1 770 km) along the Pacific seaboard.

A main and a protection radio frequency channel operating in the 2 000 Mc/s band will be provided on all routes. In the event of failure or degradation of the working radio channel, changeover to the protection channel is automatic.

Each radio channel has a capacity of 240 speech channels.

This important contract was secured by the ability of the G E C to meet a short in-service date and by the reputation for reliability which G E C microwave equipment has already earned in many countries of the world.

The equipment will be engineered and manufactured by the Transmission Division at Telephone Works in Coventry.

Revolutionary Lamp for New Lighthouse

It is intended to bring into operation shortly the first Trinity House lighthouse which is designed for operation from a central control point. This lighthouse is situated at Dungeness, Kent and incorporates a new type of lamp, a little over 12 inches (205 mm) in length and under 2 lb (907 g) in weight, with a simple drum lens as the optical system in contrast to the large rotating lens (weighing up to five tons) which has been used in the past with either a continuously burning paraffin vapour burner or tungsten filament lamp as the light source. The new type of lamp is the Mazda 2 kW high pressure Xenon arc discharge lamp.

The lamp and lens combination are of small physical size and comparatively low weight and the lighthouse is designed as a slim tower with a height of 115 feet (35 m) and a diameter of only 12 feet (366 cm), giving a rather pleasing 'pencil' design.

The new light is of about 300 000 candle power and a special method of operating the Xenon lamp has been developed by Associated Electrical Industries Lamp and Lighting Co Ltd, and Trinity House. The light source, although small, is intense and may be flashed on and off instantaneously at a power of 2 000 W at the correct intervals. In the case of Dungeness the light flashes 1·3 seconds every 10 seconds.

The principal advantage of the new equipment is the substantial reduction in size and complexity of the optical arrangement and in addition a reduction of power required to operate the light.

The electricity supply to the equipment is by batteries which may be trickle charged from the mains.

A Unique Pumped Storage Scheme

THE North of Scotland Hydro-Electric Board has placed orders for the manufacture and installation of the large pumping and generating plant required for the Cruachan pumped storage power station of their Loch Awe scheme, claimed to be the largest project of its kind in the world. The machines will consist of four reversible pump turbines with four 100 MW motor generators. Two of the sets will be supplied by the English Electric Co Ltd, and two by Associated Electrical Industries Ltd.

The equipment is the first of its kind to be manufactured in the United Kingdom. It is unique because, instead of a separate pump coupled to the same shaft as the power-producing turbine, a single-stage combined pump-turbine will be used. This will rotate in one direction when generating power and in the opposite direction when pumping.

The decision to use reversible pump-turbines shows a significant technical achievement. For the first time a single-stage reversible pump-turbine will be used to operate under a head of water of over 1 100 feet (335 m), while a number of new technical arrangements in design have been incorporated.

The 400 MW Cruachan pumped storage power station, which will be situated underground in the heart of the Ben Cruachan mountain, will be the major station in the Loch Awe scheme, which has two conventional hydro-electric stations at Inverawe and Nant. At night and also at week-ends, when the demands for electricity are low, the electrical part of the machines will be used to drive the hydraulic part to pump water from Loch Awe to a reservoir formed by a dam, the crest level of which will be over 1 300 feet (396 m) above sea level, to be built across a circular hollow on the mountain side of Ben Cruachan at the head of Cruachan Burn.

During the hours when there is a peak demand for electricity, water will be fed down the sloping shafts to the power station nearly 1 200 feet (366 m) below and the process then reverses, the hydraulic machines acting as turbines. Water will be conveyed to and from Loch Awe through a tunnel below the loch level.

Work is already in progress on a tunnel 3 600 feet (1 100 m) in length and 21½ feet (6·55 m) wide which will provide access from Loch Awe-side to the machine hall of the underground power station. This tunnel will have a 17 feet (5·18 m) wide carriage way. An access road from the Dalmally/Oban road to the Cruachan dam site is also being built.

Technical Details

Each electrical unit is rated at 100 MW as a generator and 120 MW as a motor at 500 rev/min. These machines will operate at 1 600 V on a 3-phase 50 c/s supply. At this speed they will be the most powerful hydro-electric units in the world. Each machine will be of the vertical type; a single thrust bearing located in the upper bearing housing is designed to take the weight of the rotor, the hydraulic runner and the hydraulic thrust. There is a top guide bearing also located in the upper bearing housing and a second guide bearing is mounted below the rotor.

The thrust bearing will be of the 'spring mattress' type provided with pressure lubrication for starting.

A closed air-circuit ventilation system will be fitted to each machine, the air being cooled by air/water heat exchangers mounted on the stator frame. In order to obtain the maximum cooling efficiency, external motor-driven fans will be used to circulate the air through the machines, since fans mounted on the rotor are relatively inefficient when designed to operate in both directions of rotation.

The stator core will be built up of laminations made from a recently developed low-loss cold-reduced sheet steel which has a surface finish superior to that of hot rolled material. This superior surface finish makes it easy to build a very tight and uniform core.

The stator coils will have main insulation of mica tape bonded with a modified epoxy resin, a type of insulation not previously used on machines of this size in Britain. Its advantages lie in its ability to withstand the effects of differential expansion resulting from the frequent starting up and shutting down inherent in pumped storage installations.

For operation as a pump motor each machine will be started by an a c pony motor mounted on the shaft. This method of starting restricts the starting current to less than one-quarter of the full-load current, thus avoiding the difficulties associated with violent load variations on the supply lines.

The rotors of the electrical machines will be built up of thin punched sheet steel segments, thus ensuring a homogeneous rotor body and facilitating erection on site. These machines will be the first large hydro-electric units operating at 500 rev/min to have this type of rotor construction.

Automatic control equipment will be provided to enable the machines to be started and stopped by means of push-buttons. Automatic voltage regulators of the Magnestat type will be supplied.

Cruachan is the second major pumped storage project in Britain, the first being the Central Electricity Generating Board's scheme at Blaenau Ffestiniog,* North Wales, for which Associated Electrical Industries Ltd have supplied the four 75 MW, 16 kV, 428 rev/min generator-motors. The first machine at Ffestiniog is now being erected on site.

The main difference between the Blaneau Ffestiniog and the Cruachan schemes is that at Ffestiniog each generator-motor is coupled to a separate pump and turbine and rotates in the same direction whether generating or pumping, while at Cruachan the functions

* THE BEAMA JOURNAL, **68**, No 3, pp 86–89

of pump and turbine are carried out by one reversible unit.

During the peak load hours, water flowing from the upper reservoir to the lower will drive the hydraulic runner and the electrical machine will operate as a generator. During off-peak periods the electrical machine will be run in the opposite direction as a motor driving the hydraulic runner and pumping the water back to the upper reservoir more than 1 000 feet (305 m) above.

The units supplied by Associated Electrical Industries Ltd will be manufactured at the company's Rugby and Glasgow factories, and the pump-turbines, which will be sub-contracted to Boving & Co Ltd, London, will be manufactured almost entirely on the Clyde by John Brown (Clydebank) Ltd.

The English Electric equipment, consisting of two 142 000/136 500 h p reversible pump turbines and two 111 MVA motor-generator units, complete with governors and 80-ton (81 284 kg) valves, will mainly be made at the Scotstoun works of Harland & Wolff Ltd, where many other English Electric water turbines and generators have been made for the North of Scotland Hydro-Electric Board.

In the last seven years English Electric and Sulzer have developed special designs of both turbines and generators for pumped storage schemes in view of the growing world-wide interest in this form of power generation.

The largest installation of single-runner reversible pump turbines in operation is at the Sir Adam Beck station near Niagara Falls, where six 55 000 h p English Electric Deriaz units have been in operation for four years. At present three 100 000 h p Deriaz reversible units are being built for a major pumped storage project on the Tagus River in Spain.

With the encouragement of the North of Scotland Hydro-Electric Board, water turbines and generators for Scottish hydro schemes were first manufactured at the Scotstoun works of Harland & Wolff Ltd in 1947 under an agreement with English Electric. This agreement brought a new industry to Clydeside. Scottish engineers, skilled in shipbuilding, turned their skills to the manufacture and assembly of heavy mechanical and electrical equipment.

The Highland schemes—the first was Loch Sloy—have provided a shop window for British hydro plant manufacturers. The establishment of a home market in water turbines and generators has been a source of operational experience which has proved an invaluable asset in negotiation with overseas buyers. For example, information on the performance of an automatic voltage regulator installed at the Loch Sloy station has enabled English Electric to obtain orders from the U S A for very large water-wheel generators controlled by this type of regulator. These important contracts were awarded to Britain in face of fierce international competition. In its turn, experience gained by the company in overseas markets has brought advantage to Scotland both in technical development as well as stable employment in a new post-war industry.

English Electric plant made at Scotstoun has been exported to the U S A, Canada, South Africa, Australia, Tasmania, New Zealand, India, Rhodesia and Nyasaland, Spain and Brazil. To date, turbines totalling over three million h p and generators totalling nearly two million kVA have been made at Scotstoun, over 70 per cent of them for overseas. The North of Scotland Hydro-Electric Board has given great encouragement by ordering equipment for 18 different power stations.

Second A S E E Exhibition Dinner

THE second annual dinner organised by the Electrical Engineers (A S E E) Exhibition Ltd, at Grosvenor House, London, was attended by nearly eight hundred people representing all branches of the electrical and allied industries, Government departments, and overseas diplomatic services. Mr R. F. Mathieson, A I E E, chairman of the exhibition company, presided.

The toast of 'The Electrical Industry' was proposed by Air-Marshal Sir Herbert Spreckley, Controller of Engineering and Equipment, Air Ministry, who emphasised the tremendous developments in the 'electrics' of aircraft over the past 37 years. Sir Charles Westlake, chairman of Metal Industries Ltd, responded.

The toast of 'The 1962 Exhibition' was proposed by Sir William McFadzean, chairman and managing director of British Insulated Callender's Cables Ltd and chairman of the Export Council of Europe. He stressed the importance of a really well-staged display of first class products; there was no better way, he said, of supporting propaganda and salesmanship. He commended the Electrical Engineers' Exhibition and was confident that it would go from strength to strength.

Mr Mathieson, in replying to the toast, said that most of the sponsors' publicity effort had been devoted to telling potential overseas buyers about the exhibition and about the arrangements made for the convenience and comfort of visitors. The attendance at the 1961 exhibition was 76 000, and this figure included some 800 visitors from 88 countries overseas. The organisers were sure that the 1962 exhibition would be a colourful and exciting display; it would include a special feature devoted to 'Electricity in Aviation'.

Mr Mathieson concluded by saying that the organisers were ready to meet changes in industry, in economic policy, and in the nature of exhibitions generally. All these points were being carefully considered.

The Eleventh Electrical Engineers' Exhibition will be held at Earls Court, London, from March 20 to 24, 1962.

The BEAMA Golden Jubilee Dinner

LEADERS of the Government, industry, the public services, and ambassadors of overseas countries were among the distinguished guests at The BEAMA Golden Jubilee Dinner at Grosvenor House, London, on October 31, when the principal guest was the Prime Minister, the Rt Hon Harold Macmillan, M P. The BEAMA's President, Mr Anthony M. Browne, was in the Chair.

Proposing the toast of 'The British Electrical and Allied Manufacturing Industry', the Prime Minister referred to the enormous progress that had been made. In Britain over the past 60 years the output of the industry had increased about 30 times, so that it had doubled every decade. The combination of scientific knowledge and engineering skill had consistently given Great Britain more and cheaper power, and this process was still continuing. The curious thing was that, unlike everything else in the Prime Minister's experience, it had got cheaper. Only four years ago power stations cost a little under £60 per kilowatt to build, but the stations which would come into service two years from now would cost under £40 per kilowatt. This was indeed a great achievement.

Fine Export Record

Apart from the benefits which electrical appliances had brought to every home and the gains from cheaper power to manufacturing industry at home, the electrical industry was a great earner of foreign exchange, with £300 million of overseas earnings last year. This was a record, and a fine record, and the movement was going forward at the same rate. There had been a notable increase in exports everywhere and particularly to Europe.

The President of The BEAMA, Mr Anthony M. Browne (right), *welcomes the Prime Minister, the Rt Hon Harold Macmillan, at The BEAMA Golden Jubilee Dinner. Mr S. F. Steward, Director of The BEAMA, is seen in the background*

'You in the electrical industry are playing and will continue to play a great part in this', he said. 'In many activities the United Kingdom is in the lead. We are building giant power plants and heavily stressed transmission systems. We have in execution the world's biggest civil nuclear power programme. We have ships at sea powered by new ideas in electrical propulsion. In our factories we are increasingly installing finely regulated electronic controls, and other electronic equipment is carrying out calculations which would otherwise be, it seems, far beyond human power. The tradition of your industry in research is very fine'. The Prime Minister paid a tribute to The BEAMA which had served the industry for so many years so well. In this country the Association had played a leading part in establishing the Electrical and Allied Research Association and the British Standards Institution, and on the international plane the World Power Conference owed its origin to the vision and drive of The BEAMA's first director. Among trade associations, The BEAMA was remarkable for its many-sided activities and its promotion of exports, and he congratulated the Association on the successful and stimulating Export Conference held earlier in the month.

Commenting on the Common Market discussions, Mr Macmillan said: 'Your industry is so well organised, so buoyant and progressive, that it has little to fear and much to gain from an increase in the broad markets out of which prosperity can be won and by which we in the more developed countries can play an even greater role in our assistance to the under-developed countries'.

Viscount Chandos Replies

The Rt Hon Viscount Chandos of Aldershot, Past-President of the Association, responded to the toast. He said that if we looked forward to continued expansion and to higher standards of life in this country, the electrical and the chemical industries must be amongst the leaders. The electrical industry's output of machinery and apparatus was about £1 600 million a year and its exports were around £300 million.

He referred to the industry's efforts to improve its efficiency in order to sustain the large expenditure on research and development necessary to keep it in the forefront of progress, and to the industry's careful planning for many years ahead—an activity in which The BEAMA has given a great deal of assistance.

Mr Anthony M. Browne said the Prime Minister had made the Jubilee Dinner a great and memorable occasion. 'We are very proud of the tributes paid to the record of our industry, to its technical achievement, to the contribution which it has made to the economy of the nation, and to the success which it has achieved in the markets of the world'.

New Electrical Machines for Teaching Purposes

THERE is at present world-wide discussion concerning the teaching of electrical machinery theory. For many years this has been taught by traditional methods, each type of machine being considered in turn, starting with the transformer and proceeding with the d c machine, the induction machine and the synchronous machine. Then the 'special' machines such as the Schrage motor were dealt with later if time permitted. This approach covered steady-state working only and transient operation was dealt with later and only to a limited extent.

During the last few years a new approach to the whole subject of electro-mechanical energy conversion has become apparent. The new approach stems from the original writings of Gabriel Kron, who suggested over 25 years ago that all electrical machines are specialised applications of a completely general 'primitive' machine. This approach deals with each individual machine type as a special case of the general machine and considers steady-state operation as a special case of transient operation. Full understanding of the transient operation of machines has now become very important, particularly in regard to machines as elements in control systems.

Some earlier attempts to present the new approach tended to be highly mathematical and have therefore been given only to students specialising in electrical power after an earlier course of lectures following the conventional pattern.

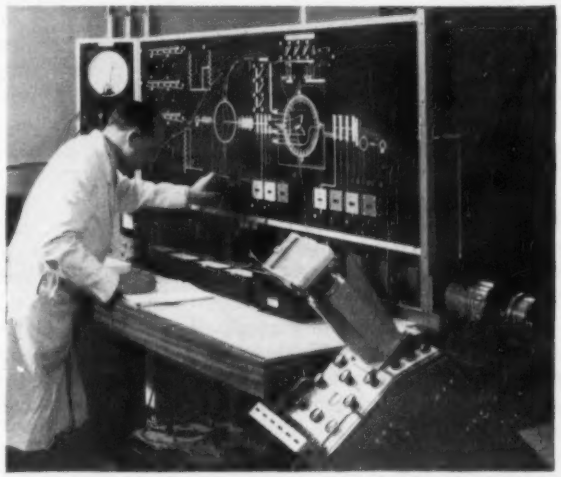
This article describes two new generalised electrical machines for teaching purposes. The first is manufactured by Associated Electrical Industries Ltd, and the second by Mawdsley's Ltd.

General Theory

The general approach to electrical machinery has great elegance and may be very briefly described as follows. Most electrical machines have a stationary member and a rotating member separated by an air gap. These members in most machines carry windings, either embedded in slots or wound around poles. The windings are coupled by the magnetic flux, most of which crosses the air gap and links the windings on both the stationary and the rotating members.

Machines which have d c magnetised poles (such as the simple d c machine and the synchronous a c machine) have two axes of symmetry, the so-called direct axis (in line with the poles) and the quadrature axis (at 90° elec to the former on the interpolar line). If, for other machines, the distributed windings on both stationary and rotating members are replaced by equivalent windings arranged on the two axes of symmetry, the relationships between the currents and voltages in the two sets of windings become very simple.

A machine which has two axes of symmetry, with windings on both axes on both stationary and rotating members, may be called a primitive machine. In actual machines some of these windings may be non-existent; thus, for example, there is no quadrature axis winding on the stationary member of a simple d c machine without interpoles. In other machines there may be several additional windings on one or both axes, *e g* the amplidyne usually has several control windings on the direct axis.



The photograph shows the control panel of the Associated Electrical Industries generalised electrical machine installed in Queen Mary College at the University of London

It will be noted in the foregoing that no mention has been made of connecting the windings of the two members together electrically. It is this connection of the windings of the primitive machine in various ways, and the excitation of the windings with either alternating or direct current, that give rise to the many types of actual machine which exist.

Teaching Approach

It will be clear from this brief description of the general theory of electrical machines that the equations of all machines can be simply obtained—almost automatically once the methods have been learned—from the relationships for the currents and voltages in the windings of the primitive machine. In setting up such equations account is taken of e m f's due to rotation as well as those due to mutual and self-induction, and allowance is also made for resistance. The equations are then transformed appropriately to take account of the method of entry to the windings, and any constraints consequent

upon the connections between individual windings and the connections to the electrical supplies are finally applied. The mechanical equation follows simply from the application of the principle of the conservation of energy. The resulting equations of performance will be completely general and include both steady-state and transient conditions.

The fundamental simplicity of this approach to electrical machine theory is very attractive, particularly when it is compared with the old piece-meal approach, in which the unity of operation of all electrical machines is lost beneath a welter of detail. Such matters as saturation of iron, commutation, and other topics, are important in practical machines and must be studied, but they need not be brought into the subject at too early a stage.

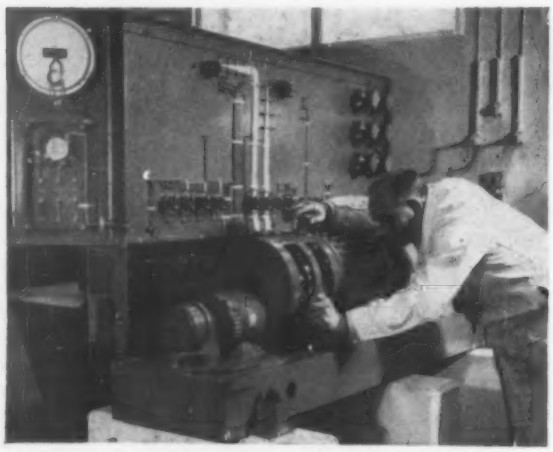
It is felt that the fundamental general approach to this subject is basically the right approach. But it is of vital importance that it be firmly grounded in a physical understanding. There is a certain danger that students who are taught the general theory will become merely mathematical 'handle turners', without that real understanding of the working of electrical machines which an engineer ought to have. A lecture course using this approach from the start must take account of this danger, and such a course needs a parallel laboratory course including experiments with a generalised machine.

The A E I Generalised Machine Set

It was for this purpose that the A E I generalised machine set was first planned at the end of 1959. It was described to the Professors' Summer School held in Rugby in 1960 and is now in physical existence.

The set incorporates a generalised electrical machine coupled on a common baseplate to a d c shunt machine for motoring and loading. The coupling forms a torque-measuring device for indicating both transient and steady-state torques.

The generalised machine can be connected for operation as any one of the conventional types of electrical machine, such as d c shunt, series, compound or cross-field excited motor and generator, induction machine, synchronous machine, a c commutator motor, repulsion motor etc. It can also operate in one unconventional mode, being equipped with a small auxiliary motor for continuously rotating one of the sets of commutator brush gear. It is limited in so far as the stator winding is distributed and so no account can be taken of saliency effects.



The rear view of the A E I generalised electrical machine

The generalised machine is the ideal machine for teaching as it brings into sharp focus the underlying unity of all means for converting energy from the mechanical to the eletrical form, and *vice versa*. It can be used to illustrate the principles of energy conversion using 1-, 2- and 3-phase windings as well as commutator and slip ring windings, and it enables the validity of the mathematical transformations relating these to be verified. In association with a cathode ray oscilloscope, camera, pen recorder and function generator, it can be used in studies of electrical and mechanical transient problems associated with all these machine types, *e g* synchronising torque of the synchronous machine and speed transients of the d c machine.

A major advantage of the generalised machine in teaching is that a number of such machines installed in a laboratory permit all students to carry out the same experiment at the same time. In laboratories equipped with conventional machines only, it is not possible for all students to perform their experiments immediately following the lectures that they are intended to illustrate and develop. The installation of a number of generalised machines solves this problem and provides other major advantages. One of these is the simplicity of demonstrating the experiments, only one demonstration or pre-laboratory conference attended by all the students being needed for each laboratory period. Another very important advantage is that the flexibility of the generalised machine allows almost unlimited scope for the initiative and enthusiasm of the good student, who can extend his formal work as he wishes. The possibilities open to him will be evident when the details of the machine are described.

Detailed Description of the Set

This generalised machine has 32 stator slots carrying a 4-pole, 2-phase winding arranged in sections for connection, as required, in series, series-parallel or parallel. The rotor has two separate windings in 24 slots: one is a 3-phase lap winding suitable for mains voltage, and the other a wave-wound commutator winding, with one dead coil, connected to a 95-segment commutator. The latter winding has four tappings at 90° elec and three tappings at 120° elec, giving six tappings in all, one being common. Five search wires are included in the stator arranged from end to end of slots 1, 2, 8, 9 and 10 and therefore the effect of various pitches can be studied. (A full-pitch stator coil occupies slots 1 to 8.) A search wire connected between one slip ring and earth is included in a rotor slot.

There are two sets of commutator brush gear, each carrying effectively four brushes spaced 90° elec apart. (As the machine has four poles, there are eight equally spaced brushes per set, with pairs in parallel.) One set is connected to flexible leads and can be adjusted in

position round the commutator over an arc of 180° elec. The other set is connected via slip rings and is continuously rotatable, being then driven by a small shunt motor at speeds up to about 500 rev/min.

Connections to the other slip rings are made through readily accessible movable links, which are adjusted in position to select the rotor winding required, namely:

(1) the three ends of the 3-phase winding;
(2) the four tappings on the commutator winding at 90° elec;
(3) the three tappings on the latter at 120° elec.

The commutator brush gear is arranged in halves for the operation of the machine as a Schrage motor. When one of the halves is being continuously rotated as described above, the other is out of use with the brushes lifted. The two sets of commutator brushes can be locked at any position, scales being provided to indicate the angular position and the angular separation.

As already stated, the generalised machine is coupled to and mounted on a baseplate with a d c shunt machine for driving and loading it. The coupling is arranged to measure instantaneous torque—an essential feature in a machine of this type—by use of the magnetostriction effect in a steel tube under torsion. An excitation coil along the axis of the tube is fed from an oscillator through slip rings, and magnetises the steel tube. This rotates within a stationary secondary winding which has induced in it a voltage proportional to torque. The absence of slip rings in the secondary circuit eliminates most of the spurious effects associated with some earlier torque measuring devices.

Electrical tachometers are arranged to give the instantaneous speeds of the rotor and of the rotating brush gear. The rotor tachometer is a 4-pole a c generator which enables transient load angles to be studied when the machine is running as a synchronous machine. A neon lamp is provided adjacent to one coupling to allow steady-state load angles to be observed.

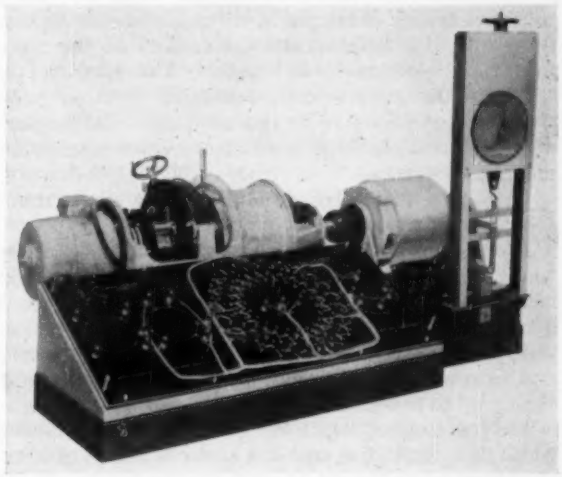
The Scope of the Machine

The set is versatile and gives a large variety of possible operating modes. With the four-to-one choice of the number of stator turns in series, the stator winding can function as a shunt or series winding, a compensating winding, an induction machine secondary winding, a synchronous machine field winding or a Schrage motor secondary winding, etc. The number of turns has been selected so that the stator ampere turns on each polar axis are approximately equal to 50, 100 or 200 per cent of the rotor ampere turns for the same axis current.

It is not intended that the set should be used entirely to replace the conventional machines in the college laboratory but rather to help in the establishment and development of the new teaching techniques. The student would measure the parameters of the machine, set up the equations of performance, and check their solutions by tests on the machine, particular emphasis being paid to transient conditions.

It will be appreciated that the characteristics of the machine in each of its modes of operation are not precisely those of an industrial machine specially designed for the particular mode. This is not considered to be of great importance in educational work, in which emphasis is placed on principles rather than on practical details. Useful discussion following an experiment could centre on the differences between the characteristics observed and those of machines specially designed for the mode of operation studied.

The second generalised electrical machine manufactured by Mawdsley's Ltd has also been specially designed to provide complete facilities for demonstrating in one machine the complete range of operating modes of every type of a c and d c motor and generator.



The Mawdsley generalised electrical machine which can be used for an unlimited range of experiments in laboratory courses at all educational levels, as well as post-graduate research

Experiments on this set serve to emphasise the fundamental unity of the principles of all electrical machines as well as illustrating the reasons for the differences in the design of individual machine types.

The flexibility of this machine set is such that the variety of experiments which can be performed is almost unlimited. This flexibility derives from certain novel features incorporated in the design of Mawdsley's generalised machine, and from an entirely new arrangement of the winding connections on a specially designed terminal board. These result in a machine set which is significantly different in principle from any of the various laboratory machines which have appeared hitherto.

The generalised machine set is suitable for use in laboratory courses at all educational levels. It is equally satisfactory for illustrating either the new unified approach to electro-mechanical energy conversion or, at the most elementary level, the inter-relationship between the performance characteristics of the standard machine types. Furthermore, it will provide considerable material for research projects at both graduate and post-graduate levels.

Description of the Mawdsley Machine

The complete generalised machine set consists of the generalised machine itself, a d c machine, and a torque measuring unit. In addition, there is a built-in a c tachogenerator for measuring the rotor speed, supplied with a dial type indicator. The machine set is so designed

that it gives maximum accessibility for demonstration and maintenance purposes.

The generalised machine and the d c machine are coupled together and mounted on a fabricated steel bed-plate. The torque measuring unit is a completely separate unit, involving no electrical connections to the rotating shaft.

The stator of the generalised machine has a conventional 4-pole a c winding in 48 slots. The ends of all 48 coils are brought out to 96 terminals symmetrically arranged in four concentric circles. Thus the stator windings can be connected in either 2-phase or 3-phase form and, by suitable inter-connection of the coils, for several different pole numbers. The principles of some of the most recently-developed types of pole-changing can therefore be demonstrated. The position of slot No 1 is clearly marked on the stator exterior for reference purposes.

There is a search coil wound round a single stator tooth.

The rotor of the generalised machine has a 4-pole lap winding in 36 slots. This winding has a set of six symmetrical tappings to both sets. Special provision is made for connecting these tappings to four slip-rings in various ways.

A search coil round a single rotor tooth is permanently connected to two further slip-rings.

The commutator, which has 144 segments, is equipped with two sets of brush gear and a pair of search brushes.

One set of 12 brushes is similar to the racking brush gear of a Schrage motor. Connections to all 12 brushes are brought out to the terminal panel. A second set of four brushes can be fixed in any desired position, or driven round the commutator at speeds up to 750 rev/min by means of a separate overhung brush carriage motor. Connections to these brushes are brought out to the terminal panel via slip-rings.

The search brushes with variable span of 0 to 8 commutator segments can be used to measure voltages between segments at all points round the periphery of the commutator.

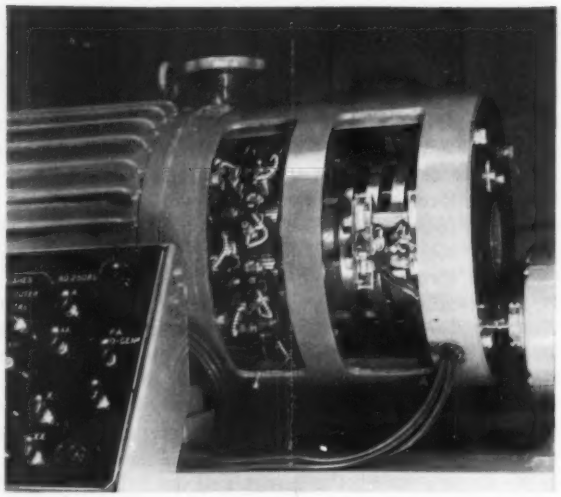
Scales are provided to permit measurement of the displacement of all brushes.

Provision has also been made for shorting together all the commutator bars by means of a specially-designed ring. This produces a semi-squirrel-cage winding which responds to the various pole numbers which can be produced by the stator winding.

Provision for Severe Overloads

The nominal rating of the generalised machine *as a 3-phase 4-pole induction motor* is 4 b h p at 240 V 50 c/s and 1 400 rev/min. The machine will however withstand severe overloads of the type regularly encountered in educational laboratories, and the insulation has been so treated that a maximum winding temperature of 110 deg C as measured by thermocouple can be tolerated. Provision is made for temperature measurements by means of a thermocouple and a mercury thermometer.

The d c machine may be either a standard machine or the well-proven swinging frame dynamometer as used in several other Mawdsley educational machine sets. The



The commutator endshield, showing the hand-operated brush gear, motor-operated brush gear and slip rings of the A E I machine

frame of the dynamometer carries the field system and is mounted in pedestal trunnion bearings. A torque arm with a simple reversing linkage is connected at a radius of 0·5 m to a spring balance calibrated in Newtons. The movement of the swinging frame is restricted by stops above and below the torque arm.

The torque measuring unit utilises a radically new method of measuring the effects of the changes in permeability which occur in planes at angles of 45° to the axis of a shaft subjected to torsional stress. The unit has been specially developed for Mawdsley's from a larger one which has given excellent service in industrial control applications, and is itself of considerable educational value. It consists essentially of a main component and the associated excitation and measuring equipment. In appearance and construction the main component is similar to the stator of a small electrical motor having the shaft in which the stress is to be measured.

The torque measuring unit is in fact a single completely self-contained device which can be used for the measurement of transient and steady-state torques in any generalised machine of Mawdsley's manufacture. Furthermore it can be used with several other machines in the new range of Mawdsley educational machines.

The Place of the Machine Sets in Teaching Laboratories

The methods used in teaching electrical machine theory are at the present time undergoing a rapid change. Several engineering schools in Great Britain already teach a generalised machine theory in the final year of their undergraduate courses as a special and additional course to the more or less conventional one of the previous year. It may well be that with the growth of fundamental scientific knowledge having a bearing on electrical engineering, the amount of new material taught will continue to increase. It is also evident that one or more generalised electrical machine sets possessing the mechanical and electrical features described above will soon be an essential part of the modern electrical power laboratory.

Drakelow 'B' Power Station

THE official opening of Drakelow 'B' power station on October 20 brings to completion the second of three stations known as Drakelow 'A', 'B' and 'C'.* When the three stations are complete they will have a total installed capacity of 2 170 MW, the largest concentration of generating power in the U K.

The first stage of the site development was commenced in May 1950 and completed in November 1955 when the fourth unit of the 'A' station was commissioned.

The 'A' station, comprising four 60 MW turbo-generators, with four 515 000 lb/hr (233 600 kg/hr) boilers and associated plant, was designed and constructed with many works which would serve the 'B' station. These works include the wagon sidings, water-treatment plant and the river water intake works; the control room, welfare facilities and administration building, stores and workshops were sited centrally between the two proposed stations so as to be equally convenient to both.

The 'B' station houses generating units No 5 to 8, each of 120 MW capacity, and with the commissioning of No 8 unit in December 1960 the second stage of development was reached. The 'B' station, being in line with the 'A' station and sharing the common administration buildings, was designed to harmonise with the earlier station in its layout, cladding and other architectural features.

The third stage of the development commenced in May 1960 with the preliminary works for the 'C' station. This station, which is to be clad with asbestos cement sheeting, will house two units each of 350 MW capacity, and two units each of 375 MW capacity.

Steam Raising Plant at Drakelow 'B'

There are four single-drum reheat boilers each with an evaporative capacity of 860 000 lb/hr (390 000 kg/hr) with feed water at a temperature of 435 deg F (224 deg C) at the economiser inlet. The boilers are of the radiant type having primary and secondary convection superheaters, convection reheaters, economisers, main and mill air heaters, forced and induced draught fans, fuel pulverising plant and automatic oil-burning equipment. In addition, Nos 6, 7 and 8 boilers have radiant primary superheaters. The steam conditions at the superheater outlet are 1 600 lb/in^2 (113 kg/cm^2) and 1 010 deg F (543 deg C) reheating from 697 to 1 005 deg F (369 to 541 deg C) at 367 lb/in^2 (25·8 kg/cm^2) between the high-pressure and intermediate-pressure cylinders of the turbine. On No 5 boiler the primary superheater is in two stages and is self-draining, while the secondary superheater is also in two stages but is of the pendant type.

The convection reheater is of the two-stage draining type. On Nos 6, 7 and 8 boilers the superheater consists of radiant and two-stage convection sections, all of which can be drained. The reheater is in three stages and is self-draining.

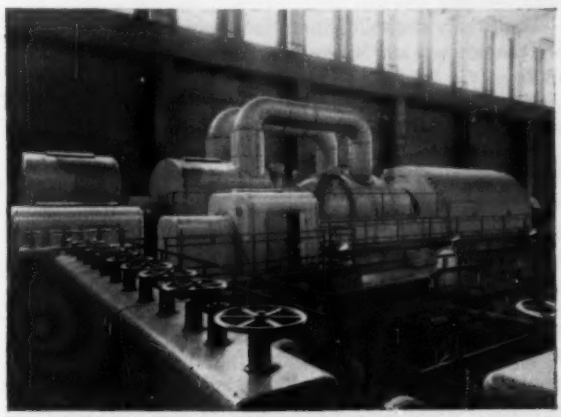
On No 5 boiler the main superheater temperature control is by an interstage de-superheater, while reheat control is by tilting burners, with spray de-superheaters in the reheater inlet pipe work for emergency use. Gas by-pass dampers and gas recirculation fans allow the temperatures at the superheater and reheater outlet to be varied manually under abnormal operating conditions. On Nos 6, 7 and 8 boilers the main superheater control, which is of the condenser type, is effected in the heaters between the drum and the radiant superheater. Steam temperature at the reheater outlets is automatically controlled by by-pass dampers with the provision for emergency use of spray de-superheaters in the reheater inlet pipework.

Two heaters of the rotary regenerative type are provided for each of the four boilers. Each boiler has two forced-draught fans and two induced-draught fans, the former of constant speed and the latter of two-speed design with inlet vane control.

On No 5 boiler there are five suction-type roller mills, four only being required to maintain full load on the boiler. On Nos 6, 7 and 8 units there are three double ended ball mills for each boiler, two of which are required for full load operation, the third being standby. On all boilers the dust and grit carried by the flue gas are removed by centrifugal collectors and electrostatic precipitators.

Turbogenerators and Associated Ancillary Plant

The four 120 MW sets, which are arranged longitudinally in the turbine room, run at 3 000 rev/min and are of the three-cylinder impulse-reaction type with a triple-flow low-pressure cylinder.



One of the 120 MW turboalternators installed in Drakelow 'B' power station

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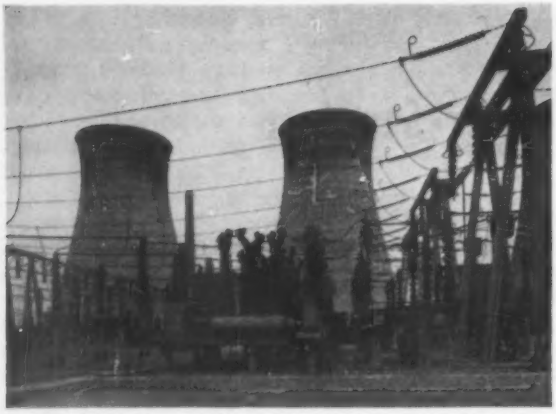


The 275 kV substation at Drakelow showing the 7 500 MVA air-blast circuit-breakers

The main speed governor controls the high-pressure steam-admission valves, and an independent auxiliary governor is fitted to regulate the intercepting and unloading valves, an arrangement allowing the auxiliary governors to be set independently of the main governor.

Steam for feed-water heating is bled from the turbine at six points to three low-pressure feed heaters including a high-level de-aerator, three high-pressure bled-steam heaters and an evaporator vapour condenser.

The steam from the exhausts of the low-pressure cylinder flows into a two-shell condenser of the three-flow surface type designed to give a vacuum of 28·9 inches (730 mm) of mercury when supplied with 58 000 gallons/min (264 000 l/min) of cooling water at 58 deg F (14·4 deg C). Air is removed from the condensers by three 50 per cent duty Mirrlees Watson pumps.

The two 100 per cent duty extraction pumps discharge through two low-pressure feed-water heaters to the de-aerator and thence to the feed booster pump inlets.

With each turbine is provided a twin double-effect bled-steam evaporating plant producing a net gained output of 40 000 lb/hr (18 000 kg/hr). The hydrogen-cooled alternators, generating at 13·8 kV, are rated for continuous operation at 120 MW at 0·9 power factor with a hydrogen pressure of 15 lb/in² (1·055 kg/cm²), distillate being used in four heat exchangers for hydrogen cooling.

The totally enclosed air-cooled main and pilot exciters are gear-driven at 750 rev/min from the main alternator shaft.

The automatic voltage regulator is of the quick-response static type incorporating a magnetic amplifier and a twin amplidyne set. The equipment incorporates a follow-up mechanism which permits a smooth change-over from automatic to manual control. Each turbo-generator is fitted with supervisory equipment to indicate and record the speed, output, eccentricity and differential expansion.

Water Treatment Plant

River water is used for boiler feed make-up. Prior to evaporation, the water is softened and ammonia removed in a plant comprising a precipitation unit with chemical proportioning gear, stabilising units and base exchange ammonia removal units. This plant has a capacity of 20 000 gals/hr (91 000 l/hr) and, with two 1½ million gallon (6·8 million l) capacity reservoirs for softened water, supplies both the 'A' and 'B' stations.

Feed Pumps

There are two 100 per cent duty booster pumps discharging through the high-pressure heaters to the inlet of two feed pumps. The latter are each 100 per cent duty and they discharge through feed-regulating valves to the boiler. Each booster pump is paired with a boiler feed pump, the standby pair starting up should either of the running pumps fail. The feed pump discharge pressure on No 5 unit is 1 950 lb/in² (137 kg/cm²) and 1 970 lb/in² (138·5 kg/cm²) on Nos 6, 7 and 8 units. The booster and feed pumps are all of the centrifugal constant speed type.

Coal Handling Plant

Small coal, with a small percentage of slurry of a calorific value within the limits of 7 500 to 11 000 Btu/lb (4 165 to 6 111 kg cal/kg) is used as fuel for the station. This is obtained from the neighbouring South Derbyshire coalfield and the Leicestershire and Nottinghamshire coal areas. Main deliveries to the station, which average 5 600 tons (5 689 860 kg) per day for the four boilers, are by rail and are handled by three-side discharge wagon tipplers having weighing facilities each of 500 tons/hr (508 024 kg/hr) capacity. The wagons are brought from the full sidings by locomotive and are then dealt with by mechanical handling plant. The three tipplers and wagon handling plants are controlled from rooms above the three wagon tipplers. From the tipplers coal can be taken direct by belt conveyor at a rate of 1 000 tons/hr (1 016 050 kg/hr) to the four 1 300 tons (1 320 860 kg) capacity boiler bunkers where it is discharged by travelling trippers, or to store where a travelling wing tripper operates on a conveyor running the full length of the coal storage area. Spreading on store is carried out by mobile coal-moving equipment, which includes two tractor shovels fitted with 5 and 8 cu yd (3·8 and 6 m³) buckets respectively, and a bulldozer. The coal is reclaimed from store by this equipment through three ground hoppers, each of 500 tons/hr (508 024 kg/hr) capacity, and provision has been made for a fourth if required later. Coal is taken from two of these hoppers by conveyors direct to the station bunkers and from the other hopper via the main reversible store conveyor. Road-borne coal is discharged either direct to a ground hopper or to store. The three tipplers are each provided with dust-extraction plant. Two marshalling yards have been provided to handle full and empty wagons for both the 'A' and 'B' stations, shunting being carried out by diesel locomotives. Magnetic separators are necessary on the conveyor belts feeding No 5 boiler bunker to prevent damage to the mills associated with that boiler, the ball mills on the other boilers making such a precaution unnecessary.

Ash and Dust Handling Plant

Ash and clinker from the combustion chambers, collected in dry ash hoppers beneath each boiler, are disintegrated and ejected by water jet nozzles and conveyed to the

ash sump by further jets in the removable nickel-cast-iron lined sluiceways. Three 50 per cent duty sluicing pumps with a capacity of 1 900 gals/min (86 373 l/m) are provided.

The fines, which are removed from the flue by centrifugal collectors and electrostatic precipitators, drop into storage hoppers. They are then removed by vacuum induced by hydraulic ejectors, permitting the air-borne solids to mix with the ejector water to form a slurry, which is conveyed to the dust sump by gravity along brick-lined sluiceways. Dust and ash slurries are removed from the respective sumps by three 100 per cent duty ash pumps and two 10 per cent duty dust pumps and transferred to disposal sites comprising exhausted gravel pits at Drakelow and Branston. Two 100 per cent duty grinders are installed. Excess slurry from the ash and dust sumps is taken to an overflow sump from which it is pumped to the ash launder of the 'A' station.

Steam Pipework

The main and hot reheat steam pipework is of 2¼ per cent chromium, 1 per cent molybdenum, steel. All steam pipework has butt-welded joints. The left- and right-hand main steam pipes are cross-connected, and similarly the reheat return pipes to the turbines, in order to permit on-load test tripping of either of the turbine stop valves or either of the intercepting valves of the reheat lines.

Circulating Water System

Water for condenser cooling is drawn from the tower ponds by four condenser pumps which discharge into a common 54 in (137 mm) diameter pipe, any pump being able to supply any condenser. From the condensers the water is taken through similar pipes to a discharge culvert and thence to the river. A cill maintains the level in this river culvert from which three tower pumps deliver water to the towers. Each of the three towers is of sufficient capacity to enable one unit to operate at continuous maximum rating.

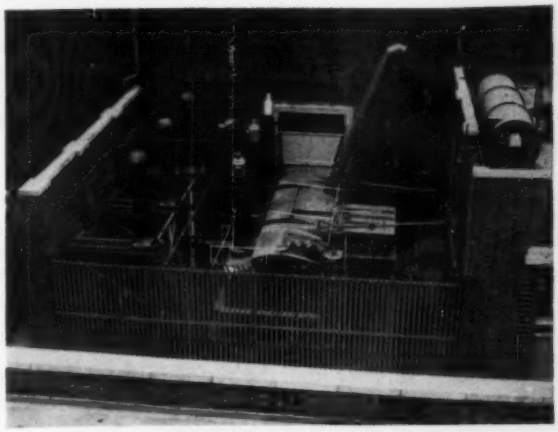
The mixed flow system, which is interconnected with that of the 'A' station, is designed to utilise, as far as possible, the available cooling capacity of the River Trent. All pumps are rated at 62 500 gals/min (282 000 l/min), the condenser pumps at 43½ ft (13 m) head and the tower pumps at 57 ft (17 m) head.

Supplies of river water for direct cooling and make-up purposes are obtained from a pumphouse constructed with the 'A' station and situated at the riverside. There are four vertical spindle centrifugal pumps, each of 2 000 000 gals/hr (9 100 000 l/hr) rating, with four cup-type screens installed at the intakes. The water is conveyed to the 'A' and 'B' stations through twin concrete culverts which discharge to the cooling tower pond and conduit systems.

The two cooling towers associated with 'B' station are of ferro-concrete construction and are 307 ft (94 m) high, the capacity being 3·82 million gallons (17·3 Ml) of water per hour.

Chlorination Plant

Master vacuum solution feed chlorinators installed with the 'A' station are used, each chlorinator being designed for a maximum capacity of 250 lb (113 kg) of chlorine per hour, with automatic intermittent operation controlled from an electric programme clock.



A generator transformer of 125 MVA capacity

Plant Control Room

There are two control blocks arranged in the auxiliaries bay between the turbine room and boiler house, in each of which is an air-conditioned room with double glazing and sound insulation, housing the control panels, desks and recorder panels for two units.

All instruments for automatic control of the boiler, coal pulverising plant and turbine are located in this room, together with the remote controls for auxiliary motors, turbine supervisory equipment and alarm systems. High-pressure and temperature steam and water connections have been eliminated from the control room by the extensive use of telemetering.

Immediately beneath the control room is an auxiliaries room in which are located miscellaneous relay panels and contactor control gear, and a dust-tight enclosure giving full maintenance access to the underside of the control desk. Below is a cable and wiring marshalling room, and beneath this, at ground floor level, is the main unit and station 3·3 kV and 415 V auxiliaries switchgear.

Station Control Room

The main electrical control room for the 275, 132 and 3·3 kV systems of both the 'A' and 'B' stations is situated in the administration block, and houses a generator load desk for the 'A' station; 275, 132 and 3·3 kV systems alarm relay equipment panels; the automatic voltage regulators for the 'A' station, and the generator relay panels and chlorinating programme clock for both stations.

Transformers

Each alternator is solidly connected by double angle section copper busbars on porcelain insulators in a reinforced concrete flume to a 13·8/295 kV 125 MVA forced oil circulation water-cooled generator transformer, the machines being switched and synchronised at 275 kV.

A 10 MVA unit transformer is solidly connected to the 13·8 kV terminals of the alternator, this transformer providing unit supplies to the 3·3 kV auxiliaries. Two

20 MVA 132/3·45 kV station transformers, each comprising two 10 MVA banked units, are provided for general station services and standby and starting supplies to the 10 MVA unit transformers.

Eleven 1 MVA 3 300/435 V transformers provide medium voltage supplies for the smaller auxiliaries, lighting and other services.

All transformers are of the oil-filled outdoor type and, with the exception of the generator transformers, are cooled by natural circulation. A fixed jet spray water installation for detection and extinguishing of oil fires is provided over all important transformers.

Auxiliary Supplies

The auxiliary supplies from the various unit and station transformers have been grouped into unit and station switchboards for distribution purposes.

The arrangement of the station transformers and various interconnectors affords maximum flexibility and enables the system to operate at the maximum capacity of the switchgear under all conditions.

All the 3·3 kV and 415 V unit and station switchgear is accommodated in two switch-houses on the ground floor of the control block. The 3·3 kV switchgear is of the single busbar air-insulated, air-break, solenoid-operated type, having a short-circuit rating of 150 MVA, the 415 switchgear being similar with a rating of 25 MVA. The 3·3 kV system is earthed through liquid-type neutral earthing resistances, the 415 V system being solidly earthed.

Motors above 120 h p are switched direct at 3·3 kV and 415 V, motors in the range of 100 to 120 h p are controlled by 415 V air circuit-breakers, the remainder of the 415 V auxiliaries being controlled by air-insulated contactor control gear. The essential standby motors for the turbine oil and hydrogen systems operate from the main station batteries. The majority of the motors are of the squirrel-cage type, started direct on line, the induced-draught fan motors being two-speed with on-load changeover facilities. The exhauster feeder and separator motors on No 5 unit are of the variable-speed, alternating-current commutator type.

A large number of auxiliary motors are installed, ranging in capacity from 2 700 h p for the boiler feed pumps to fractional h p machines used for control functions. The total installed capacity of the motors is approximately 60 000 h p.

This picture shows the modern control room at Drakelow. This air-conditioned room houses the control panels, desk and recorder panels for No 5 and 6 units

Switchgear

The 275 kV outdoor switching station comprises 17 air-blast circuit-breakers controlling four generators, eight feeders, one bus-coupler, two bus-section switches and two 275/132 kV, 120 MVA auto-transformers.

The air-blast circuit-breakers have a rupturing capacity of 7 500 MVA with six breaks in series per phase and are pneumatically operated. The 275 kV isolators are electrically operated and are remotely controlled from the electrical control room.

High-Voltage Cables

The connections from the four generator transformers switched at 275 kV to the outdoor sub-station are made by single-core oil-filled cables, having a section of 0·4 sq in (258 mm²) per phase. These 275 kV cables formed one of the first installations to go into service in this country.

Contractors and Equipment

Among the main contractors and the principal sub-contractors were the following BEAMA member-firms:

Allen West & Co Ltd—control gear; Aiton & Co Ltd—evaporators and pipework; Associated Electrical Industries Ltd—generator and station transformers and 415 V contactor gear; Bushing & Co Ltd—high voltage bushings; British Insulated Callender's Cables Ltd—main and auxiliary power and control and instrument cables; Crompton Parkinson & Co Ltd—unit transformers and instruments; Davidson & Co Ltd—mechanical dust collectors and fans; Davenport Engineering Co Ltd—cooling towers; Drysdale & Co Ltd—circulating water pumps; English Electric Co Ltd—motors and fuses; Fuller Electric Co Ltd—tap changers; General Electric Co Ltd—275 kV isolators and lighting; E Green & Son Ltd—economisers; Gwynnes Pumps Ltd—pumps; James Howden & Co Ltd—air heaters; Hick Hargreaves & Co Ltd—quick start air pumps; Harland Engineering Co Ltd—feed pumps, booster pumps and motors; Lancashire Dynamo & Crypto Ltd—motors; Laurence Scott & Electromotors Ltd—motors; Mather & Platt Ltd—fire fighting equipment; Mitchell Engineering Co Ltd—wagon tipplers and plant; Mirrlees Watson & Co Ltd—rotary air pumps; Micanite & Insulators Co Ltd—high voltage bushings; Nalder Bros. & Thompson Ltd—instruments; C. A. Parsons & Co Ltd—turbo-alternators and condensing plant; P. & B. Engineering Co Ltd—thermal relays; Pye Ltd—television equipment; A. Reyrolle & Co Ltd—switchgear, current and voltage transformers; Standard Telephones & Cables Ltd—alarm equipment; Steatite & Porcelain Ltd—low and high voltage bushings; South Wales Switchgear Ltd—415 V fusegear; Sturtevant Engineering Co Ltd—precipitators; Taylor Tunnicliff & Co Ltd—porcelain insulators; Yorkshire Imperial Metals Ltd—condenser tubes; Yorkshire Electric Transformers Co Ltd—station transformers.

The Second Electronic Computer Exhibition

THREE years after the first one—a whole computer-generation later—the Second Electronic Computer Exhibition took place at Olympia, London, in the early part of October. It brought into focus the changing scene of computing, and enabled the spectator to survey the developments of the past few years. Computers are now used by industry to a far greater extent, and the most noticeable effect of this has been the orientation of computer design to users' requirements.

The variations in the needs of users are catered for in a number of different ways. For business data processing, much use is made of modular construction and expandable systems. Small basic units for simple installations can be augmented as required until a powerful data processing centre is achieved. At the same time more special purpose computers are produced, to meet, for example, the particular needs of process or operations control.

The lesson that has been firmly driven home over the past years has been the need to use computers economically. Concentration on this aspect has led to the development of faster input and output equipment capable of making full use of computer speed; to the evolution of business computer languages and programme libraries to ease programming, and to the construction of faster and higher-capacity computers to reduce the cost per computation. This last development in turn has encouraged the introduction of time-sharing techniques, enabling a computer to work at full capacity by using it to solve several problems at the same time. A further development in hand is the use of data transmission to enable a central computer to process data sent in from a number of out-stations.

All these developments are indicative not only of the vigour of computer design in this country but also of the extent to which computer users are making their needs felt. There were far fewer 'artist's impressions' of computer installations at this exhibition and many more examples of computer applications.

The computers on show certainly deserve the title 'second generation'. Speeds of calculation have gone up by a factor of 100 in some cases and solid-state circuitry has become the rule rather than the exception. The use of high-speed ferrite core storage has increased greatly, and so has the use of magnetic tape for high-capacity stores. Magnetic tape has the advantage of high density of information storage together with rapid 'writing' and 'reading' of the information.

Air Traffic Control

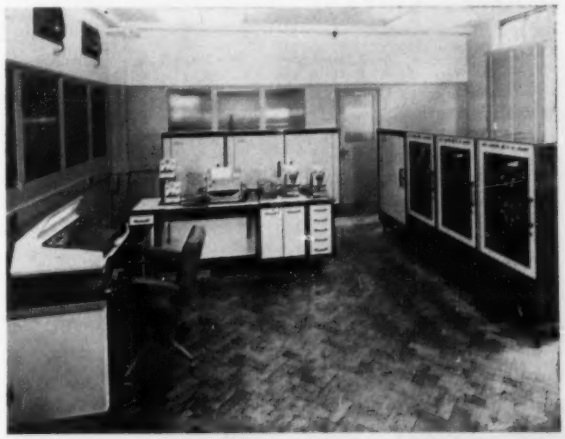
Standard general purpose digital computers are extremely flexible in their application. They can be programmed not only to perform 'off-line' business and scientific work, where the computer works to its own time schedule, but they can also be used for 'on-line' applications where the computer is connected directly to a process or operation, working in real time.

Elliott Brothers (London) Ltd exhibited their latest version of the '803' general-purpose computer and demonstrated three different 'real time' applications. Associated with the 803 was a small amount of special electronic equipment to enable the computer to receive information from five different input sources and to feed six different output devices. The input and output modes, and the techniques demonstrated in each of the three cases, were selected entirely by the programme fed into the computer. This process took less than a minute and demonstrated the flexibility of the machine. No manual switching was required between demonstrations.

The three demonstrations consisted of: a comprehensive electronic airline reservation system; an automatic telegraph switching centre; and air traffic control procedures.

The air traffic control demonstration involved the use of three on-line teleprinters. The function of each was different and each represented one or more instruments in an actual situation. One teleprinter was used for the input of basic flight plan data, normally derived from the flight clearance offices of airfields served by an air traffic control centre. The second represented a number of such machines used by controllers within the centre. The third represented a telecommunications network over which messages were passed between centres.

Flight plan data entered at a flight clearance office is stored within the computer along with previous input data on other aircraft. After the flight data is entered, corrections or amendments may be incorporated. At some predetermined time before the planned departure,



A Model 803 Elliott general-purpose digital computer installed in the premises of a large manufacturer. The installation comprises an operator's console (left), a 'paper tape station' and the 803 computer itself on the right

the flight plan information is printed out to the relevant controller at the centre. This is followed by detailed information on the proposed route of the aircraft with estimates of elapsed time between successive reporting points and flight-levels at these points, assuming an unrestricted departure. In the demonstration, this information was printed on the second teleprinter immediately after entry in the first.

On receipt of a clearance request from an aircraft, the controller may check for potential conflicts by entering on his teleprinter his estimate of its departure time. Conflicts predicted by the computer are printed out to the controller, giving full information on the conflicting aircraft.

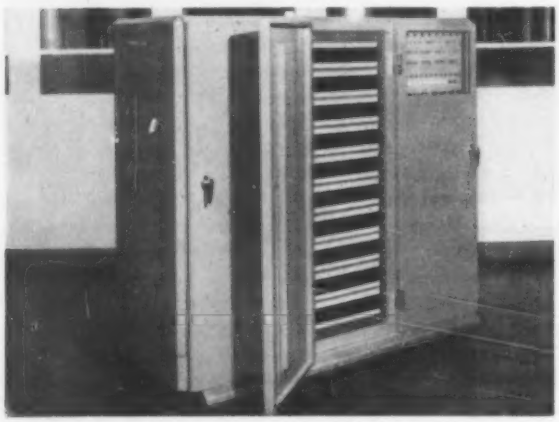
Having given a clearance to an aircraft, the controller at the centre enters the details, which may include flight level restrictions, on his teleprinter. When the aircraft has become airborne he enters the departure time and the computer prints out on his teleprinter the time estimates and flight levels at successive reporting points along the route, together with results of a further conflict check. At this stage a departure message is automatically printed on the adjacent centre's teleprinter.

Position reports are received at the centre from the aircraft as it passes each reporting point. The information received is fed to the computer by way of the controller's teleprinter, causing a revision of all time estimates and heights for succeeding reporting points, as well as a re-examination of the conflict situation. The revised information is printed out on the controller's teleprinter.

When the position report for the last reporting point in the Flight Information Region has been received and entered, the computer will print the transfer-of-control message on the adjacent centre's teleprinter. After transfer to the adjacent region, all data on the aircraft may be erased from the computer store at the controller's discretion, by the entry of an erase message on his teleprinter.

While this is a relatively simple demonstration, it illustrates the potential usefulness of a digital computer in assisting an air traffic controller by relieving him of many of the calculations which he has to perform.

It was fascinating to see the computer switched at short order from performing this on-line task to carrying out seat reservation or telegraph switching—quite unrelated tasks of a similar complexity.



The main unit of the Ferranti 'Argus' process control computer. This computer uses solid-state components throughout

Seventy-one 803 computers have been sold to customers throughout the world, and the latest version incorporates several improvements over earlier models. Operating speeds have been increased considerably and a battery power supply has been built into the system to cushion the computer from the effects of fluctuation in mains voltage supplies and power failures.

The latest innovation is a paper-tape station designed to group together all paper-tape input and output devices in a single unit. This speeds up tape handling. The ferrite-core storage can be backed up by four magnetic film storage units, giving virtually unlimited storage capacity. Another 803 system on the stand was shown carrying out calculations on problems of civil and aeronautical engineering, scientific statistics, and operational research.

The company also exhibited a full-scale model of the new '503' computer, a machine 100 times as fast as the 803. It retains full programme compatibility with the 803, and so uses the established library of programmes.

Also displayed on the same stand, by Panellit Ltd, was the Panellit '609' industrial information and computing system. This is already in one-line operation in chemical plants, oil refineries, nuclear and conventional power stations, and steel works. The 609 scans continuously measurements received in the form of electrical signals from up to 1 000 points, and checks that these are at required levels. It provides warning of any dangerous conditions or variations in efficiency of operation.

The central processing unit of the 609 is the Elliott 803 computer. Included in the system are Panellit 'Minilog' solid-state switching elements for connecting-in the multiple input and output equipments. A printed record of conditions throughout the plant is produced at regular intervals. The equipment also calculates the efficiency of operation of selected sections of the plant or of the plant as a whole, and provides management with the information necessary to operate the plant at its most efficient level. This same information could also be used for the direct automatic control of the plant.

Coal Gasification

Ferranti Ltd showed a model of a coal gasification plant linked to their Argus computer. The computer dealt with coal feed, gas quality, steam feed, oxygen feed, and boiler and compressor house control. Argus is one of a range of six computers that Ferranti are now producing and has been specifically designed for the direct control of industrial plants and processes.

Argus is equipped with a time-sharing facility which enables it to work on several control programmes simultaneously. Information can be read in from as many as several hundred instruments in a plant, subjected to necessary mathematical operations, and then used to generate any required number of output signals for control supervision or logging purposes. The unit uses binary fixed point arithmetic and the word length can be 12 or 24 binary digits. With 12 digit numbers, simple instructions are performed at the rate of about

50 000 per second. There is a high-speed working store of ferrite cores with a capacity of 1 024 words and backing-up storage of 50 000 words can be provided by magnetic drum.

Programming of the machine is done normally by inserting small pegs of magnetic material into holes drilled in printed circuits, which are arranged in trays. The capacity of the programming store is made to suit the customer's requirement. For one current application it is 1 024 instructions.

The most powerful computer in the Ferranti range—and in the world—is the Atlas. The first production model is now being installed at Manchester University and the control desk was put on show at the exhibition. A second has been ordered by the National Institute for Research in Nuclear Science, Harwell. A third has been ordered for the University of London. The British Petroleum Company is providing about a quarter of the cost of the third and in return will be able to use it for the full-scale integration of their refinery and supply programme.

The University has been using a Ferranti Mercury Mark II computer since 1959 and, although this was one of the fastest machines available in Europe when it was installed, it is now inadequate to cope with the size and range of computations required. The Atlas computer will not only be nearly 100 times faster than Mercury but will have a much greater capacity for handling numbers. It is a general-purpose machine for both scientific calculation and data processing and has been developed in co-operation with the University of Manchester. Original technical features include a supervisory system for regulating the flow of work through the machine, a 'page-address' system for more efficient use of storage space, a new type of semi-permanent store for frequently-required data, and an adder with exceptionally fast carry-over. Simple instructions (for example, addition) can be performed at a speed approaching a million a second.

Accounting and Inventory

E M I Electronics Ltd had an Emidec 1100 computer working on their stand and also demonstrated an Emidec 2400 working at the E M I factory at Hayes, Middlesex, by means of closed-circuit colour television. It normally takes 5 to 6 weeks to commission an Emidec 1100 on a customer's premises, with a further week for acceptance tests. At Olympia there were only 5 to 6 days to install the computer and make it fully operational.

E M I decided that it was not possible to install their complicated Emidec 2400 computer at the exhibition in the few days allowed. Therefore colour television cameras at the company's Hayes plant transmitted panoramic views of the installation in action and close-up shots of its various components by micro-wave link to Olympia, a distance of 10 miles (16·1 km). A two-way sound link provided the exchange of comments and questions between Olympia and Hayes.

Among the computer programmes demonstrated were part of the payroll at the Longbridge factory of the British Motor Corporation; a stock control programme, and typical hire-service applications such as fixed-interest yield tables.

The Emidec 1100 has been sold to a variety of customers. J. Sainsbury Ltd, a large grocery company, are using one to control over 250 000 separate stock levels at their branch shops. Accurate control of stock is of great importance in handling perishable foodstuffs. A future application will be that of dealing with orders for highly-perishable items supplied to the shops on a day-to-day basis. Emidecs are also being used by the British Motor Corporation, Glaxo Laboratories (manufacturing chemists), and Boots (the multiple retail chemists) for dealing with sales invoices, accounting and the preparation of sales statistics. The Ministry of Labour is using one for processing statistical returns relating to employment, earnings and prices; and the Air Ministry uses one for payroll work.

E M I now offer three new items of peripheral equipment for use with this computer. The first is a paper tape reader operating at 1 000 characters/sec. The second is the Anelex printer producing 740 lines of characters per minute. The third is a new magnetic tape transport in which tape speed will be increased to 150 in/sec (381 cm/sec) and the packing density increased to 267 bits/in (105 bits/cm).

The Emidec 2400 data processing system uses solid-state elements throughout, and while its design is based specifically on the needs of commerce, business, and industry, the company say that this does not preclude the on-line use of the high-speed computing unit for scientific applications. In the central computing unit, 1 Mc/s transistor-diode logic with circuit elements, having switching times of about 0·2 microsec, are used. All units are built up from a small number of plug-in printed circuit panels. Magnetic cores provide computing storage; and fast start-stop 1 inch (2·54 cm) magnetic tapes interconnect and route data through the system.

The central computing unit operates from high speed magnetic tape and each of the peripheral units works from or prepares a similar magnetic tape. Under a master control plan all units in the equipment operate independently, information being passed from one unit to another by the switching of tapes. To give flexibility,

An Emidec 1100 computer being used for stock control and central accounting in a chain of large provision stores. It is believed that this is the first use of a computer for stock control problems

this switching can be controlled either manually from a control desk, or from a master programme in the central computing unit. When a number of different processing jobs is being performed the master programme becomes a necessity to take full advantage of available speed.

One of these machines has been ordered by the Ministry of Pensions to handle the work involved in the new Graduated Pensions Scheme involving about 14 million employees. It will operate with 19 magnetic tape units, a card/tape converter, two search units, and a Xeronic printer. Payments will be recorded in the computer system from April 1962. Before this can be done, files of basic records for 26 million employees have to be set up on magnetic tape. The punching of this information on to 27 million cards was started in the spring of 1960 and will not be finished until 1962. After card-to-magnetic tape conversion, about 1 000 hours of computer time will be required to sort these records and produce the final file in readiness for operational use.

File Processing

The central unit for data processing systems ordered by the Royal Air Force and by the National Coal Board was shown by Associated Electrical Industries Ltd (Electronic Apparatus Division). It was the A E I 1010, a solid-state machine capable of controlling as many as 32 single purpose peripheral units simultaneously. These include output printers operating at up to 3 000 lines/minute, magnetic tape units, and punched card and tape equipment.

A design engineer at work on an Associated Electrical Industries Ltd 1010 computer. The panel seen in background is mounted on a swinging frame for ease of access

A 1010 system containing two computing units and many magnetic tape stores and peripheral units was ordered recently by the Air Ministry. It will operate a typical file processing system on a very large scale. Demands for equipment and supplies from depots and units in the United Kingdom and overseas will be transmitted over telegraph circuits to a supply-control centre near London. There the computer will maintain records of R A F requirements, holdings, stock consumption, procurement and repair contracts, re-distribution of stock, consignments in transit, etc, all on magnetic tape. By means of parallel programming, the computer will also give over-riding priority to urgent demands without interrupting routine operations. It will be capable of processing such demands within 7 or 8 minutes. Records of about 750 000 items and 2 million incoming messages a month will be handled by the system.

The Scottish Division of the National Coal Board has ordered a 1010 data processing system as a step towards unification of data processing throughout the whole coal industry. The first installation will handle wage and salary calculations for 90 000 people. It will also undertake materials and supplies accounting—involving costing and processing of 14 600 stores items a day—and will record the despatch of 4 500 loads of coal a day.

Successors to DEUCE

On the stand of the English Electric Co Ltd, parts of the KDP 10 and KDF 9 computers were on show for the first time. These are the company's new generation computers, succeeding their Deuce, and they have orders amounting to £2½ million already in hand. Also to be seen was a complete KDN 2 system—a small general-purpose computer using the company's 'Datapac' units.

KDP 10 is a commercial system and the KDF 9 a general-purpose one. Both use transistorised printed circuits. KDP 10 systems have been ordered by the Commercial Union Insurance Group, the Yorkshire Electricity Board, and the Midland Bank. The high-speed store is a random-access magnetic core device which provides storage for programmes and data. Capacities up to 260 000 characters are available. Tape selection and buffer units allow the connection of up to 8 tape stations to the computer and control the interchange of information between them and magnetic tape. Up to 62 magnetic tape units can be controlled by the computer. The main output is from a high-speed line printer operating at 600 lines a minute, each line having up to 120 characters.

The general-purpose KDF 9 can be equipped with a wide range of peripheral devices, including those associated with the complementary KDP 10 system. English Electric claim there is no practical limit to the total number of devices that can be connected to the system and that any number can operate simultaneously, subject to a maximum theoretical instantaneous transfer rate of 1·33 million alpha-numeric characters a second. Up to four independent programmes may operate concurrently by time-sharing in the control and arithmetic circuits. The machine is the fastest in the English Electric range: addition and subtraction in floating-point arithmetic take from 6 to 10 microseconds. Multiplication

takes 14 to 18 microseconds. In actual operation the computer speed may be increased by up to 35 per cent by means of 'time-smoothing advance control'. The function of this is to level out peak demands on the main store and on arithmetic operations; by anticipating future requirements for data from the main store and by allowing other operations to proceed during the transfer of data into the main store, a useful gain in speed is achieved. No additional programming is required.

'Slave' work with the KDF 9 or the KDP 10 is one of the possible uses of the small-scale KDN 2. It can also be used for the direct control of industrial processes, the scanning and recording of temperatures, pressures, etc, and for business and scientific computing. The Datapac units providing the logical circuitry of the KDN 2 can cover 70 different logical functions and allow the building-up of a wide range of data handling systems. The main store is a ferrite-core matrix, expandable in size up to 4 096 words; auxiliary storage on magnetic tape can be provided. Addition or subtraction of an 18-bit word takes 175 microseconds.

Electronic Seat Reservation

A temporary airline seat-sales office was set up on the stand of Standard Telephones and Cables Ltd to show the principles of operation of the company's availability and reservation systems. Visitors could enquire about the availability of seats on any Scandinavian Airlines System (S A S) flight. A link from the stand to the S A S magnetic drum store at Copenhagen enabled replies to enquirers to be obtained without delay.

A £2·5 million contract for the first part of a £4·5 million electronic seat reservation system for British European Airways has been awarded to S T C. It will deal with some 3 000 telephone callers, 280 counter callers, and 500 telegraph messages per hour. It will mean, during peak booking months, the elimination of 2½ million reservation cards, 100 000 flight control sheets, and over a million booking entries previously made by hand.

This order follows one from B O A C for an electronic seat-availability system. In 'availability' systems, reservation clerks in widely scattered offices interrogate a central information store. Up-to-date information on airline flight availability is returned to the enquiry office in a matter of seconds. A fully integrated 'reservation' system, in addition to providing an availability system, holds an inventory of seats on all flights. Such a system also stores complete passenger details such as name, address, telephone number, and special requirements for food, transport, etc.

The principle exhibit on the S T C stand was a typical Stantec computing system. This is a good representative of the type that can be built up in various sizes from a number of standard units. In terms of cost, the range extends from £28 000 for a small scientific system to £200 000 for a large data processing system.

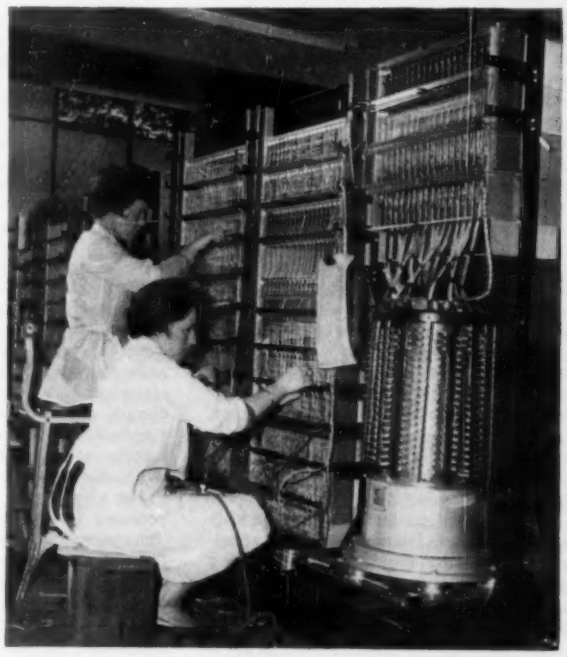
The nucleus of the range is the Stantec computer. Basically this is a transistorised version of the Zebra computer and uses the Zebra programme codes and programme library. A variety of magnetic tape equipment is available for extra storage: up to 32 tape units can be attached to the system. The K2 magnetic tape unit uses an open strip 328 feet (100 m) long, contained in two magazines and holding up to 750 000 alpha-numeric characters. Ten of these can be integrated into one frame to give a storage of 7·5 million characters. The K2S reel tape unit can store up to 9 million characters.

Data Transmission

Data transmission was demonstrated on the S T C stand by the operation of a Stantec computer at the S T C plant in Harlow, Essex, over leased telephone lines. Problems were transmitted to Harlow and the returned answers were automatically printed out at Olympia. A forward transmission speed of 1 000 bauds and a return speed of 50 bauds were used, the slow return speed being convenient for feeding signals directly to a teleprinter without the need for a buffer store.

The British General Post Office is taking an active interest in data transmission and had a stand at the exhibition. The G P O permits data transmission over the normal public telephone network but does not provide terminal apparatus. This must be obtained from manufacturers and must meet with G P O approval. There are, however, two items that the G P O has under development: a modulator/demodulator unit to convert data pulses into a form suitable for the telephone network and an error-detecting unit for use with telegraph circuits. Both will be available for renting.

For the transmission of digital data over telephone lines, Ferranti Ltd demonstrated their 'Data Link' system, sending information between the Business Efficiency Exhibition and the Computer Exhibition.



Wiring in process on a Standard Telephones and Cables Ltd 'Stantec' computing system at their Newport plant

New equipment and processes

The English Electric Liberator Tumble-wash
The latest addition to the English Electric range of domestic appliances is a single-tub washing machine designed for housewives who prefer to use their own washing 'programmes' but do not want to stand over the machine while it does its work. Named the 'Liberator Tumble-Wash', it allows for individual preference and special garment treatment. The user has personal control of the water temperature, length of wash, number of rinses and spin period, while the machine carries out the instructions automatically.

The Liberator Tumble-Wash needs no permanent plumbing, is connected to the hot or cold water supply by a single hose, is fully mobile, washes, rinses and spins in one tub so that there is no handling of wet clothes, and has four simple controls. Temperatures can be chosen to suit every type of fabric, a pilot light glows red when the heater is on, the tumble-wash action stops automatically at the end of a pre-selected time, an automatic pump allows continuous rinsing for as long as required, and the spin can be set for half a minute for crease-resistant fabrics, or longer for heavy materials.

The overall width and overall depth of the Liberator Tumble-Wash is 25 inches (63 cm) and the height to the working surface is 34 inches (86 cm).

The welded sheet steel cabinet is treated by a special rust-proofing process and finished in durable stove-enamel in white or cream. This machine is mounted on retractable castors so it can be wheeled to the sink for use, and stored away when not required. Movement of a lever at the back of the cabinet raises the machine on to the castors so that it can be moved. If a fixed installation is preferred, two extra feet can be fitted—this is necessary if the companion Liberator Tumble-Dry is to be mounted on top of the washing machine.

The door frame is of pressed steel. The inset window is moulded from thick heat-resisting glass and incorporates a soap port which enables extra washing powder to be added after the machine has been filled with water. Rubber gaskets make a water-tight seal with the cabinet. The door handle is removable to prevent children opening the door while the machine is operating. The motor is automatically switched off if the door is opened when the machine is working.

The standard motor is a continuously rated drip-proof, ½ h p single-phase capacitor start induction motor (a c only) running at 1 425 rev /min. A circuit-breaker mounted on the back panel protects the motor windings against overloading.

Quiet trouble-free performance is given by a two-speed Vee-belt transmission. The drum rotates at 60 rev /min when washing and approximately 570 rev /min during the spin operation. The change from slow to high speed is effected by a sliding sheave mechanism operated by a cable control from the front panel.

A 2·75 kW tubular sheathed immersion heater is built into a sump at the base of the outer container. This is controlled by a variable thermostat with four temperature settings. Recommended settings for various fabrics are printed inside the let-down flap on the control panel.

A clockwork timer controls the motor which powers the tumbling action, pump and spin. The timer dial is graduated up to 20 minutes. When the water has reached the correct temperature, the timer can be set to the required washing time. This will start the tumble washing action which will stop automatically at the end of the pre-set period. When the timer dial is set at rinse, the washing can be given either a continuous rinse—carried out by turning on the cold tap and the pump simultaneously so that the clothes are tumbled in a continuous flow of clear water—or a series of separate deep rinses.

The water is emptied by a centrifugal pump, which is controlled by a lever on the control panel, and a second lever controls the spin cycle. The timer can be set to give any required spin period.

The interior of the machine is left perfectly clean at the end of the wash, and no water reaches the outside of the machine, so that no special cleaning is required. (*English Electric Co Ltd*, English Electric House, Strand, London, WC2.)

Semi-Automatic Welding of Television Components
Electro Mechan-Heat Ltd, of Bilston, Staffordshire, have made two special purpose welding machines for the Ferguson Radio Corporation, who will use them at their Enfield works for high-speed production of the chassis and the turret tuner spindle assemblies of television tuner units.

The machines, designed to produce one completed component every four seconds, are semi-automatic in operation. Welding cycles are controlled by electronic units embodying interlock devices, ignitron contactors and three-stage timers with printed circuits. Welding current is obtained from standard E M H 45 kVA packaged welding transformers, connected to welding guns by flexible cables.

The photograph shows the general appearance of the chassis welding machine. The control buttons can be seen on the top front of the loading table. Beneath, within the framework of the machine, is the control cubicle, containing the three-stage timer and the ignitron contactor. The open door emphasises the ease with which the equipment can be serviced.

The chassis welder is provided with a pneumatically-operated work table, which is withdrawn from the welding position when at rest for easy loading. The pressing of two 'start' buttons energises a relay, which interlocks two push buttons to start the timer. The work table then moves forward to the welding position, where it trips a limit switch admitting air to the cylinders which operate the clamps.

Air pressure continues to build up in the clamp cylinders until it closes a pressure switch connected with an electrically-operated air valve. The opening of this valve admits air to cylinders which bring the four welding guns into position.

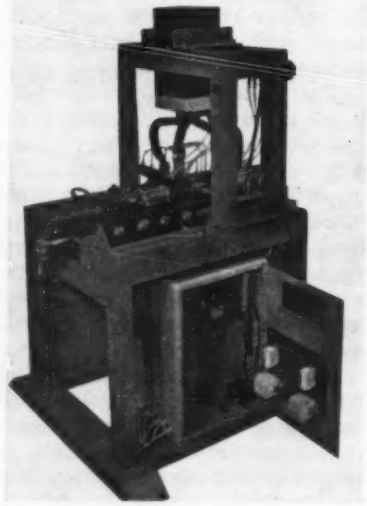
When the electrode tips make contact with the work, air pressure continues to build up in the gun cylinders until another pressure switch is closed to initiate the 'weld' stage of the timer by firing the ignitrons in the primary circuit of the transformer and so causing the welding current to flow.

The weld stage is followed automatically by a 'forge' period, whereafter the clamps are released, the welding guns retract and the work table returns to the load position. In doing so it operates mechanisms which re-set the welding control circuits and also a further pneumatic device whereby the welded component is partially lifted from the welding jig to facilitate its removal.

The welding of this component, which consists of two discs on a spindle, presented certain problems in the exact spacing and positioning of the discs.

A tolerance of only ±0·0015 inch (0·038 mm) was acceptable in the location of one of these discs relative to a groove in the spindle. The spacing between the two discs had to be accurate to within ±0·003 inch (0·076 mm); and finally, certain holes in the two discs had to be aligned to within an angular tolerance of ± 0° 15′ of arc.

To ensure accurate location of the first disc, the spindle is held by a jig, which incorporates electro-magnets. The disc is



A three-quarter front view of the television chassis tuner unit welding machine recently manufactured by Electro Mechan-Heat Ltd. The electronic control cubicle, with door open, illustrates the ease of servicing

then slid on to the spindle and the magnets energised so that the disc is drawn to an exact distance from the end of the spindle.

The second disc is held by another electro-magnet attached to the piston shaft of a small air cylinder. By this means it can be moved pneumatically to a predetermined position on the spindle relative to the first disc. Locating pins on the ends of both electro-magnets engage with depressions in the two discs to ensure their accurate angular positioning about the shaft.

The electro-magnets are operated by a foot switch, which allows the operator to engage the locating pins with the depressions in the discs before energising the magnets. But once the 'start' buttons have been pressed the magnets remain energised until completion of the full cycle of operations.

The first stage of this cycle is the moving of the second disc to its correct position along the spindle. Back pressure in the air cylinder which controls this movement is then used to actuate a pressure switch, whereby the welding gun solenoid is energised. Pneumatically-operated welding heads now move into position and back pressure in their air cylinders is used to close a second pressure switch and initiate the weld stage of the timer.

On completion of the welding cycle, the welding heads retract, the magnets are de-energised and the moveable magnet returns to the load position. The welded component is then removed and fitted into a sizing jig, which consists of a forming block with two slightly conical faces against which the discs are pressed by impact cylinders until they conform exactly to the end faces of the block. (*Electro Mechan-Heat Ltd*, Manor Works, Ettingshall, Wolverhampton.

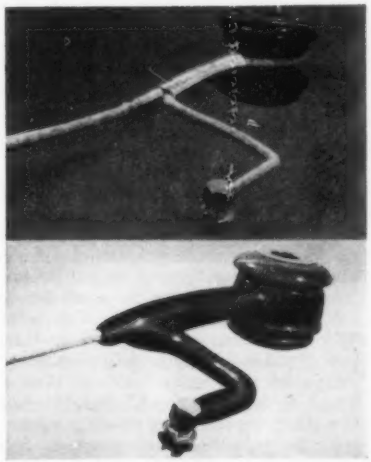
A New Universal Putty

'Talurit' plastic putty is a new material that is malleable and yet when formed sets rock hard. It is claimed to be a highly efficient electrical insulator and can be machined, drilled, tapped or threaded. It can be used to repair anything, and is suitable for sealing cracks and holes in all types of hollow piping. In fact, its applications are limited only by the ingenuity of the user.

This new plastic putty consists of two separate components—a resin and a hardener. When these two are completely integrated in equal proportions (which is easily effected in the hands), a readily workable putty is provided that will adhere to anything. It cures itself naturally in anything from 1½ to 18 hours according to the room temperature and remains dimensionally stable while at the same time attaining considerable hardness and strength, high electrical insulation qualities and exceptional resistance to oil, spirits and water. Independent tests from a number of representative samples provided the following results:

Compressive strength (ult)	11 200 lb/in² (78·7 kg/cm²)
Tensile strength (ult)	700 lb/in² (49 kg/cm²)
Dielectric strength	253 V/mil
Resistance between electrical conductors and armour	37 300 megohms
Resistance between electrical conductors and water	27 850 megohms
Water absorption	2·7 per cent

Some of the electrical applications of 'Talurit' putty include the setting and affixing of shrouding, insulating or water-proofing terminals, conductors or cable ends, cable joints, repairing or replacing porcelain and plastic insulators, bushes, terminal blocks and the like. Amongst its mechanical applications are the structural joining of materials and components, repair of leaks and weaknesses in vessels, piping or casting, and for all purposes where the putty, when cured, will require drilling or tapping. (*Cable Covers Ltd*, St. Stephen's House, Westminster, London, SW1.)



'Talurit' plastic putty used for the insulation and protection of the joint on a house service electric cable. The top photograph shows the joint before protection

New Heaters by Dimplex

A new 2¼ kW portable infra-red fire is the latest appliance to come off the production lines of Dimplex Ltd, Millbrook, Southampton. Incorporating three silica-sleeved elements in one generous reflector trough, this new fire is designed to give all-over radiant warmth from a very low level on a broad front. Each element is loaded at 750 W. The centre bar is permanently in circuit and there is separate switching for the top and bottom bars. It is therefore possible to have one, two or three bars on at a time. The arrangement of the elements also enables the user to have some control over the direction of the heat. With the top element on, the heat is directed down towards the feet, while the bottom element throws heat up into the room. The body of the fire is finished in gold stove-enamel and the reflector is heavily chromed on brass. The chrome guard is hinged at the top to allow for easy cleaning.

For the 1961/62 heating season the well-known range of Dimplex electric radiators incorporates several improved features. The built-in room temperature thermostat has been restyled to give it a less angular appearance and has been improved from the performance point of view. The control knob now protrudes from the front of the cover and is easier to operate. It incorporates a dial showing the numbers 1 to 5. If the control knob is set at 1, this is equivalent to an average room temperature of 45 deg F (7·2 deg C), at No 3—60 deg F (18·3 deg C), and at No. 5—75 deg F (23·9 deg C). These numbers relate to average room temperature, not heat output. Thus, whenever the pilot light is on, the radiator will be working at full power. When the light is off the appliance is not using electricity. In a well-insulated room the radiator may not necessarily remain warm all the time. The Dimplex radiator has been designed to maintain a steady room temperature and the surface temperature of the panel is of no consequence.

All floor-standing Dimplex panel type radiators are now supplied with a dual purpose foot. This has been designed to provide two positions from the same basic assembly. One position is for use when the radiator is required to stand on feet—the other is for use with castor wheels. All that is now required to convert the feet into a castor wheel unit is to change the position of the components and insert the specially designed Dimplex castor wheels.

There are no less than ten models in the Dimplex range of panel type radiators in loadings from ½ kW to 2 kW or, in the column type range, there is a choice of four models in loadings of 1, 1½, 2 and 3 kW. All Dimplex radiators are finished in high gloss stove enamel. They are available in bronze, gold, cream and white as standard or, to special order at no extra charge, in turquoise blue, pink, eau-de-nil, light grey and red.

The Dimplex wall-mounted infra-red heater is loaded at 750 W and is supplied with a built-in pull cord switch and is ideal for bathrooms and kitchens or any situation where quick heat is required over a defined area. It is available with either natural or copper colour anodised aluminium reflectors, with a choice of nine colours for the baseplate.

With the introduction of two new permanently oil-filled electric towel rails towards the end of last season, Dimplex now claim that they have a towel rail to meet every requirement.

The two latest models, known as Model TRC130 and TRS175, have been designed to fit into the smallest bathroom and yet give the maximum towel hanging space. They are available for either floor or wall mounting. The chrome model (Model TRC130) is loaded at 130 W and the stove-enamel model (Model TRS175), available in a choice of nine colours, is loaded at 175 W.

For providing quick background heating on a broad front, Dimplex offer skirting board styled convector heaters. Available in two sizes—2 ft (61 cm) (300 W) and 3 ft (91 cm) (500 W)—they can be used as 'floor-standing portables' (supplied with feet), or for mounting direct on to skirting boards or walls. To provide the sole means of heating they can be built up in multiples by the use of special connector sets.

Attractively finished in high gloss stove-enamel, these convectors are supplied in the full Dimplex nine-colour range.

Dimplex also manufacture Junior General Purpose Heaters for small area space heating. Styled on the familiar lines of Dimplex electric radiators, these heaters are available in loadings of 300 and 450 W. The 300 W model is handy as an airing cupboard heater and for cloakrooms, etc. The 450 W model is useful for small rooms and as an anti-frost heater in the loft or garage. Like the Dimplex radiators, these heaters are permanently oil-filled with totally enclosed elements and are fitted with excess temperature cut-outs—ensuring complete safety in operation. (*Dimplex Ltd*, Millbrook, Southampton.)

Instruments for Heavy Industry

Crompton Parkinson 'New World' switchboard instruments have 3½ inch (89 mm) diameter dials with 240 deg scales approximately twice the length of corresponding conventional short-scale instruments. Supplied in flush mounting pressed steel cases, these instruments are individually calibrated by hand against a master standard.

A full range is available, including moving-iron and moving-coil ammeters and voltmeters, wattmeters, synchroscopes, and frequency, speed and power factor indicators.

Based on a design originally developed for the Armed Services, these instruments are of extremely robust construction. The staffs of the moving elements have hardened and polished carbon steel pivots working in jewel bearings which are spring-mounted to give protection against damage due to vibration, while the complete movement is resiliently mounted inside the outer case to provide further safeguards against the effects of mechanical shock.

In the 'New World' range of industrial switchboard instruments, the dial has been brought forward so that it lies in the same plane as the front of the bezel. This ensures that the scale markings and pointer receive the maximum possible illumination and that all shadows on the dial are eliminated. It also enables the indications to be read over a very wide angle. The slightly projecting moulded glass cover is specially contoured to avoid striations of light on the dial face, and the cardinal points on the scale as well as the figures are bolder than usual. The result is an instrument with indications that are particularly easy to read even under unfavourable conditions of siting and lighting.

The 'New World' styling conforms with current practice in Canada and the U S A.

The increasing demand for Crompton Parkinson electrical tachometers has enabled the generator used with this system to be redesigned for large-scale production by the most advanced mechanised means. The substantial saving in costs thus achieved is reflected in a reduction in the price of the generator of approximately 30 per cent.

It will be remembered that these generators are of the a c three-phase pattern with no brushes or moving contacts. As such they are trouble-free in operation, while the indication on the associated instrument is steady, rapid in response and dead-beat. Overall accuracy is within 1 per cent. Standard speed ranges are from 0 to 400 rev/min for either foot or flange mounting, but extra slow speed, narrow speed band, and intrinsically-safe patterns are also available. (*Crompton Parkinson Ltd*, Crompton House, Aldwych, London, WC2.)

Electron Beam Welding

A new fusion welding process of great promise to industry generally and the nuclear and aircraft industries in particular is being manufactured by Sciaky Electric Welding Machines Ltd.

Electron beam welding is a fusion welding process, in that the principle is to join two or more pieces of metal by local melting resulting in coalescence. The joint may be produced by the combination of base metal only, or a filler metal may also be introduced.

The heat required is produced by the bombardment of the work piece by a dense beam of high velocity electrons. The beam is directed on the area to be fused and the electrons, upon striking the surface of the metal, give up their kinetic energy almost completely in the form of heat energy. The process is carried out in a high-vacuum chamber and the plant consists of the following items:

A vacuum chamber, vacuum pump system, electron gun of special design, mechanism for remotely manipulating the electron gun and the work table without breaking the vacuum, high voltage power supply and an electrical control.

Electron beam welding is uniquely suited for welding the refractory metals (tungsten, molybdenum, columbium, tantalum, etc) and the highly oxidizable metals (titanium, beryllium, zirconium, uranium, etc). However, any weldable metal or alloy and certain ceramics can be fused by means of this process. They can be joined without contamination and at a cost less than that of inert gas welding.

The equipment, in addition to welding by fusion, may also be utilised for melting, grain refining, stress relieving, out-gassing, cutting, overlaying, metallising and vacuum brazing. It is worth noting that a container closed by this method will retain an internal vacuum on removal from the chamber.

In the present missile and atomic era, many advantages are offered by the technique and doubtless many future joining problems will be solved by this method. (*Sciaky Electric Welding Machines Ltd*, Falmouth Road (Trading Estate), Slough, Bucks.)

High Voltage Medium Power Silicon Diodes

Two new ranges of high voltage medium power silicon diodes are available from Westinghouse Brake and Signal Co Ltd. The SxBR8 is rated at 18 A and may be used at case temperatures up to 140 deg C (284 deg F), while the SxBR25 is rated at 30 A and may be used at similar case temperatures. Both ranges are freely available in voltage ratings of 100 to 1 500 V peak, with ten intermediate voltages.

The diodes are hermetically sealed, using glass/metal seals and the latest press seal techniques. Mounting is by means of a stud base which also serves as the anode connection. The cathode connection is made by means of an insulated flexible lead through the glass/metal seal. (*Westinghouse Brake and Signal Co Ltd*, 82 York Way, Kings Cross, London, N1.)

Two-Pole Changeover Plug-in Relay

The type EB 2-pole changeover plug-in relay has recently been introduced by Dewhurst & Partner Ltd.

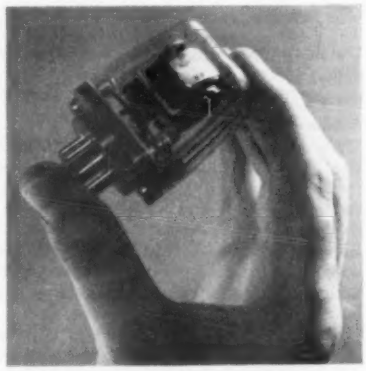
Notable for its small size, the EB relay has a wide range of applications, including control systems where continuous and frequent operation (up to 3 600 per hour) is required.

Normally supplied for coil voltages of 24 or 220 V a c, the relay is also available for voltages in the range 6 V to 110 V operating a c or d c or, with series resistor, 400 V a c or 220 V d c.

The EB relay has an international octal base fitting, but a special plug-in baseplate is available for solderless wiring. Measuring only $2\frac{3}{4} \times 1\frac{7}{8} \times 1\frac{3}{8}$ in ($69 \times 48 \times 35$ mm) overall and weighing less than 3¼ oz (92 g), the relay will operate satisfactorily in any mounting position. It is encased in clear plastic and is completely dustproof.

The solid silver contacts need no maintenance and have a life of over 10 million operations, with a normal switching current capacity of 6 A at 250 V a c or 2 A at 400 V a c.

For a c use the operating time is approximately 10 m s and the release time 8 m s, and for d c use operating and release time are both approximately 8 m s. (*Dewhurst & Partner Ltd*, Inverness Works, Hounslow, Middx.)



The Dewhurst and Partner Ltd plug-in relay

New Hoover Polisher-Scrubber

Hoover Ltd have introduced an entirely new polisher-scrubber.

The new polisher-scrubber has been designed to give equally effective polishing for floors, furniture and other surfaces and to act as an efficient scrubber.

Some of the features incorporated are that it weighs only just over 10 lb (4·5 kg) as compared with nearly 14 lb (6·4 kg) for its predecessor, yet durability is combined with this lightness by the use of a strong aluminium alloy for the base casing and by the use of shock resisting Cycolac plastic for the motor hood. It is styled in porcelain blue, with the Hoover emblem and handle release pedal in red.

One set of brushes which can be used for polishing or scrubbing and one set of felt pads are provided with the machine.

Optional extras are lambswool buffing pads and waxing and cleaning pads.

The brushes are easily fitted over projecting clips on the hexagon shafts and the pads easily clip on.

The new Hoover polisher - scrubber is designed to comply with British and overseas approvals board requirements

The base follows the contours of the two brushes which, being contra-rotating, make for stability and finger-tip control.

The provision of an overlapping furniture guard avoids splashing when the machine is used as a scrubber.

Low contours allow for operation under low furniture and a stabiliser guards against vibration.

The polisher-scrubber is switched on and off by moving the handle down or up. The foot operated pedal releases the handle from its upright position.

For easy storage it may be hung in a cupboard from a ring at the top of the handle.

The polisher-scrubber is doubly insulated to British and overseas approvals boards standards. The machine has also been designed to obviate the entry of water. The handle-operated on-and-off switch referred to above avoids the possibility of the machine being connected in the 'on' position.

A small specially designed high-speed motor operates at approximately 15 000 rev/min and by reduction gear, gives 500 brush revolutions per minute. (*Hoover Ltd*, Perivale, Greenford, Middx.)

New Fluorescent Fittings

The Lighting and Heating Group of the General Electric Co Ltd, announce a new range of fluorescent fittings. Packed complete with tube and ready for installation, this important addition to the G E C fluorescent range is called 'Slim Jim'.

'Slim Jim' offers a complete series of batten fittings in 8 feet (244 cm) 125 W; 5 feet (152 cm) 80 W; 4 feet (122 cm) 40 W and 2 feet (61 cm) 20 W sizes with single and twin versions in all except the 4 feet (122 cm) 40 W size. Instant start is standard in the 4 feet (122 cm) and 5 feet (152 cm) packs.

These fittings are packed complete with Osram warm-white tubes and embody many unique design features.

One of the primary features of the new range are the springloaded lampholders which slide neatly on grooves into the operating position and enable relamping to be carried out from either end. They require no fixing screws, being held firmly in position by the cover-plate. This lampholder design is such that it serves both the single and the twin batten fitting. (*The General Electric Co Ltd, Lighting and Heating Group*, Magnet House. Kingsway, London, WC2.)

Combined Home Freezer and Refrigerator

Combining all the advantages of a normal refrigerator *plus* zero temperature for frozen foods, a new 'Fresh and Freeze' refrigerator has been announced by The English Electric Co Ltd.

Elegantly styled in the modern English Electric square-cut 'Slimline' design, the 'Fresh and Freeze' is finished in white or cream with a neat chromium trim between the two front-opening doors to the freezer and refrigerator compartments. The freezer compartment will hold up to 50 lb (23 kg) of frozen foods and has over 4 cu ft (113 l) of shelf space. Simple to operate, the temperature control for both compartments is from one dial which gives below-zero temperature in the freezer and 40 deg F (4·4 deg C) in the refrigerators with warmer and colder settings if required.

A special feature is the automatic defrosting in the refrigerator section. The defrost water collects in a drain container which can be periodically emptied without disturbing the food in the refrigerator.

The two-door cabinet is of steel, welded and screwed construction, finished in rust-resisting stoved synthetic enamel; the freezer compartment is insulated with rigid polyurethane of high thermal efficiency, while the refrigerator compartment is insulated with glass fibre and the cabinet is mounted on two rollers at rear with levelling screws at the front.

The freeze compartment is aluminium with scratch- and acid-resisting finish, refrigerated on all four sides, providing long-term storage of up to 50 lb (23 kg) of frozen foods at *below zero* temperature and fitted with a removable shelf carrying two aluminium ice-trays with polythene cube dividers.

The machine is designed to operate in ambient temperatures up to 110 deg F (43·3 deg C). Under these conditions it will maintain temperatures in the 'freeze' compartment below zero deg F (−17·8 deg C) and cabinet temperatures just over 40 deg F (4·4 deg C).

To comply with the high humidity test, a low-wattage heater cable runs round the front edge of the freeze compartment and behind the mullion bar separating the two compartments. This heater is continuously energised.

In order to maintain the running time in cool ambients, a further low-wattage heater is fastened to the lower food compartment and this heater is energised when the compressor has switched off, thus ensuring that the 'off' cycle is not too long. This heater is brought into operation automatically by a thermostat at the rear of the cabinet which is responsive to the ambient temperature.

Frost build-up in the freeze compartment is slow, since the door is opened less frequently than the lower cabinet and there is no free liquid present. As frost grows it may be periodically scraped away with a non-metallic spatula.

If a complete defrost eventually becomes necessary, the machine is switched off at the supply and the defrost water drains to a container in the lower compartment.

The off-cycle defrosting operating in the refrigerator section results in a slightly higher humidity than the normal refrigerator. This results in less dehydration of any exposed foods; in other respects all the normal unfrozen foods may be stored here.

All current research on preservation of frozen foods indicates that 0 deg F (−17·8 deg C) is the desirable temperature for the long-term storage of frozen foods without deterioration. The English Electric Slimline 'Fresh and Freeze' refrigerator provides just this temperature automatically at the 'zero storage' setting.

Commercial freezing conditions cannot be reproduced in a freezer of this kind; nevertheless small quantities of home produce may be frozen and preserved successfully. The quantity of food to be frozen at any one time should not exceed 5 lb (2·3 kg), when the rapid-freeze setting on the control should be used. The recommended procedure is to set the control to this cold setting an hour or two before the produce is ready to be frozen.

The new Slimline 'Fresh and Freeze' will be available early in 1962. (*English Electric Company Ltd*, English Electric House, Strand, WC2.)

The new English Electric Co Ltd 'Fresh and Freeze' refrigerator with both doors open. This model has all the advantages of a normal refrigerator plus zero temperature storage of frozen foods

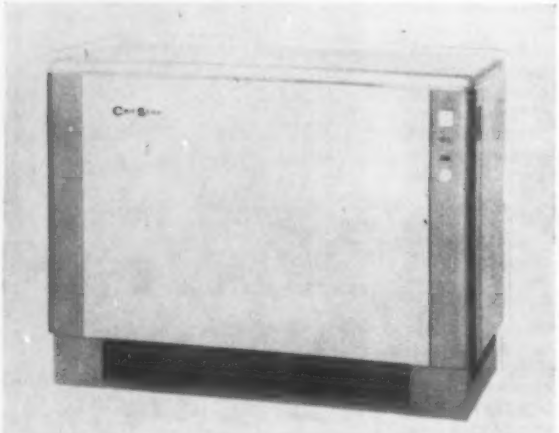
The Heating, Ventilating and Air Conditioning Exhibition

THE first International Heating, Ventilating and Air Conditioning Exhibition took place at Olympia between September 26 and October 6. After getting off to a slow start it drew increasing interest as it progressed. On show was a wide range of equipment—not only that usually associated with the exhibition's title but also industrial air treatment plant for such things as filtration, grit and fume collection, and mechanical draught. As Mr C. J. Atkins, chairman of the exhibition committee pointed out: 'Hevac is directly concerned not only with heating, ventilating and air conditioning from the comfort aspect but also with improvement of working conditions in factories, clean air, and atmospheric pollution. It is therefore of direct interest to the industrialist, works and plant engineer'. ('Hevac' is the abbreviated title of the exhibition.)

An important trend in Britain has been the growth of precision industries requiring very close control of room atmospheres. These include transistor firms and establishments producing inertial guidance equipment for rockets. Some of these factories are as nearly perfect from the point of view of atmospheric control as any factories in the world.

The exhibition covered an area of about 100 000 ft^2 (9 290 m^2) and among the 220 firms exhibiting were representatives from half-a-dozen European countries. A number of BEAMA members took part in the exhibition and their experience and the new equipment they exhibited provide pointers to the progress and character of the exhibition.

All remarked on the number of overseas visitors to the stands. A E I-Birlec Ltd put the proportion as high as 1 in 4, while others put the figure somewhat lower. Many of the overseas visitors were travelling in parties and the Rheostatic Company found that this facilitated the arrangement of follow-up visits from the stand to the factory. In general the feeling on the stands seemed to be that queries usually were searching, and that many concerned the specific problem of a user rather than a desire for general information.



The ConStor thermal storage heater shown by Bastian & Allen Ltd. Electricity is supplied to the elements during the night and stored in a special core material

Heating

A thermal storage heater taking advantage of off-peak tariffs was displayed by Bastian & Allen Ltd. This was equipped with a fan to give variable rates of heating. Electricity is supplied to the elements during night or other off-peak hours and the heat generated is stored in a special core material. Element ratings of 6·0, 4·5 3·0 and 2·0 kW are available, associated with storage capacities of 48, 36, 24 and 16 kWh. The electrical loadings are based on an 8-hour charging period, which offers the lowest tariff at night.

The heater is efficiently lagged to retain the heat until it is required. For rapid room heating the fans are switched on at full speed, which can be done automatically by timeswitch if required. Fan speed is variable, controlled by a room thermostat to keep the room temperature constant. The fan duty is such that with a heater rated at 3 kW the discharge during the first half hour can be as high as 6 kWh. With larger heaters it is even higher. This is important when considering church heating, for example, where maximum economy is required for short-period heating.

Both the preceding heaters incorporated a considerable degree of control and many other stands emphasised the growing use of control engineering in heating and ventilating. The 'Monotronic' is a new temperature controller produced by the Rheostatic Co Ltd to form a useful complementary system to their 'Duotronic' two-term controller, which is used for more complex control schemes.

The Satchwell Monotronic provides simple proportional control of temperature in heating, ventilating and air conditioning installations. It is suitable for such applications as the local control of temperature from a heater battery or the like where proportional control is required. Signals caused by temperature changes are amplified by a transistor circuit which provides proportional correcting action. A low-heat-capacity resistance is used for detecting temperature changes and a motor is provided for operating a valve or damper.

Simplicity of operation and maintenance is a feature of the Vekos-Powermaster boiler exhibited by G W B Furnaces Ltd. It is a new packaged boiler designed for

solid fuel firing and an important feature is its high efficiency—over 80 per cent—for a wide range of fuels and outputs. The unit is controlled by steam pressure or water temperature and is designed for operation within a firing range of 30 to 100 per cent load. At all settings the fuel and air are maintained at the correct ratio and the boiler will operate at low loads with high efficiency.

Basically, the new boiler consists of the Vekos stoker fitted inside a specially designed three-pass dry-back Economic boiler of a similar construction to the company's successful 'Powermaster' boiler. At the top of the furnace there is a vortex chamber with a series of slots arranged tangentially in the walls. Coal is fed radially into the vortex chamber from a vertical tube passing through the boiler crown, by means of a screw conveyor located immediately above it. The conveyor feeds from existing bunkers or hoppers and is driven through a gearbox by a 1·5 h p electric motor. A single fan supplies air for all purposes: primary air to the grate, secondary air to the vortex chamber, and tertiary air to the combustion chamber throat, roughly in the proportion 40/40/20 per cent. Maximum working pressure is 250 lb/in^2 (17·6 kg/cm^2).

Electric Surface Heaters

Industrial electric surface heaters for use in laboratories or on process vessels and pipes were shown by Isopad Ltd. The heating mantles shown ranged from standard laboratory mantles for flask heating to mantles for all types of process vessels from 5 to 2 000 gallons (22 to 9 000 l) capacity in three standard loadings. These comprise the heating surface made from Isopad glass weave, to which heating elements are attached, thermal lagging giving optimum efficiency. For very high temperatures quartz cloth and stainless steel mesh are used as the element carrier.

For pipe tracing and other applications flexible electric heating tapes were shown. These can be used straight or in spiral around the pipes.

George Bray & Co Ltd indicated the diversity of their products in the electrical fields. They were showing their comprehensive range of electrical heating elements which consist essentially of 80-20 nickel-chrome resistance wire, wound in a spiral, embedded in a refractory material for electrical insulation, and sheathed in metal to give mechanical strength.

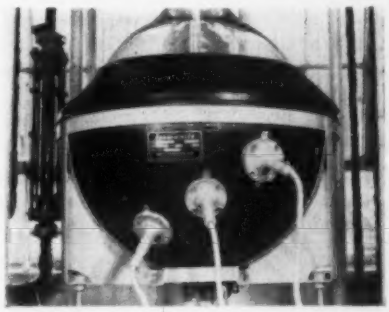
These heating elements are available in strip, ring, cartridge and tubular form, and application of these standard forms provides a solution to most heating problems. Particular reference was made in the display to the application of these elements in processes and products.

Appliances in which Bray elements are used include heating ovens, hydraulic presses, wash boilers, moulding dies, packaging machinery, oil pre-heaters, and many types of domestic appliances.

Air Conditioning

Many types of air conditioners were on view and trends to be seen were the use of more sophisticated styling and careful acoustic design to reduce noise to a minimum. The General Electric Co Ltd showed their new 'Californian' air conditioner—a floor-standing unit suitable for individual offices. It is almost silent in operation and only requires a 32 in by 16¾ in (77·2 by 42·5 cm) wall aperture and an electric power point. Much use has been made of resilient mounting within the unit and the design is such that noise is ducted out of the wall aperture and not into the room. The unit is thermostatically controlled and has a 2 kW heating element for colder weather.

For large areas such as computer rooms, laboratories, factory areas, etc, A E I-Birlec Ltd were showing their Frescan type RU equipment. This is a compact self-contained unit that removes excess heat or humidity. Connections are required for electricity and water. The complete unit is divided into lower, middle and upper sections, air from the room being drawn in through a refrigerated element in the middle section and discharged back into the room from the top section. The lower section houses the refrigerator equipment. All necessary electrical equipment, including the main isolating switch and automatic starters for the compressor and fan motors, are built into the cabinet. Various sizes dealing with from 1 200 to 8 000 ft^3/min (34 to 227 m^3/min) are available.



A pilot flask of special design for flame-proof areas. This was one of the Isopad exhibits

Davidson & Co Ltd showed their latest design of 'Sirocco' air-conditioning unit operating on the evaporative cooling principle. On a base tank fitted to receive chilled water, steam coil, or immersion heater fitments is mounted a steel air chamber fitted with a mid-feather centre division plate to form a double-pass unit. The first pass is piped internally for two or three banks of water atomising nozzles; one bank follows the air flow, the remainder oppose it. In the second pass, a double pad of nylon mesh is used as a free-moisture eliminator. On top of the air chamber is an air mixing box fitted with fresh and return air openings. Alternatively, when fresh air only is to be admitted, a preheater and air filter can be attached to the side of the box. For final control of drybulb temperature an electric or steam heater is built in on the suction side of the fan.

When operating on evaporative cooling the unit is capable of producing a 95 per cent wet bulb depression, but dehumidification and lower dry-bulb temperatures can be obtained with the use of chilled water from a cooler located alongside the unit. Unit sizes handling air volumes from 1 200 to 3 700 ft^3/min (34 to 105 m^3/min) are available.

Submarine Power Cable for New Zealand

A CONTRACT from the New Zealand Electricity Department, Wellington, New Zealand, to manufacture and install 76½ miles (123 km) of submarine gas-filled power cables, together with terminations, accessories and spares, has been placed with British Insulated Callender's Cables Ltd. The contract is valued at approximately £2 700 000.

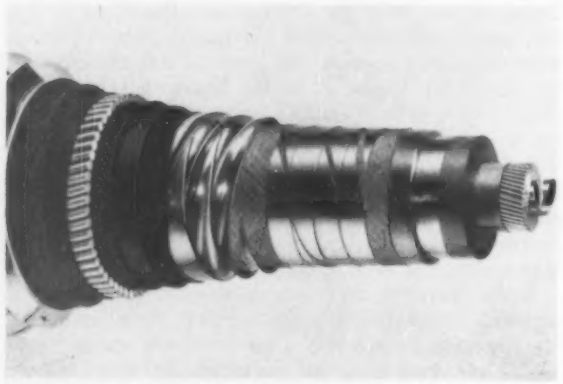
The cables will form part of a high-voltage direct current inter-connecting transmission section between existing power stations of New Zealand and will operate at a nominal voltage of plus and minus 250 kV to earth. Three single-core cables will be used; two of these will form the conductors of the direct current circuit and the other will be spare. The rated load capacity of the circuit will be 600 MW or 1 200 A.

The manufacture of the cables is being undertaken by British Insulated Callender's (Submarine Cables) Ltd at Trafford Park Manchester, and the installation by British Insulated Callender's Construction Co Ltd, both members of the B I C C Group.

Research on Trial Length of Cable

The future development of the electrical power supply in the North and South Islands of New Zealand and their inter-connection has been under review by the New Zealand Electricity Department for a considerable time. Both islands have a large hydro-electric potential and their inter-connection by submarine cable would resolve a number of problems.

In the early part of 1956, the New Zealand Government commissioned B I C C to report on the feasibility of a submarine cable crossing. Two years later, B I C C designed, manufactured and installed in the Cook Straits a sea trial length of cable. This cable was recovered in 1960, subjected to exhaustive tests and examined in the greatest detail. The cables which have now been ordered under the present contract will connect the long high voltage direct current overhead transmission lines which will be erected from Benmore power station on the Waitaki river of the South Island and from Haywards substation, north of Wellington on the North Island. A converter plant will be installed at Benmore and Haywards to convert the alternating current at Benmore to direct current for transmission, and back to alternating current at Haywards. The reason for using direct current is that it is basically a better economic proposition. Among the many difficulties that will be found in the laying of the cable is the fact that the Cook Strait is subject to severe storms and the cable laying will depend on the vagaries of the prevailing weather conditions.



A section of the Cook Strait single-core gas-filled submarine power cable, taken from the trial length laid in 1958 and recovered for testing in 1960

The Submarine Cable

The submarine cable, as used successfully for the trial crossing, is of the single-core gas-filled type, and will be manufactured without joints in continuous lengths sufficient for the crossing. A 0·80 in^2 (516 mm^2) conductor consists of a spiral steel duct over which are applied four layers of cable wires to form a conductor. The insulation is formed by paper tapes impregnated with a compound of mineral jelly which is applied over the conductor. The insulation is surrounded by nitrogen gas at a pressure of 450 lb/in^2 (31·6 kg/cm^2) and is contained within the lead alloy sheath re-inforced with steel tapes. The re-inforced cable is protected against corrosion by a vulcanised tough rubber sheath, armoured with heavily galvanised steel wires and served over all. The nominal overall diameter of the cable is approximately 5 inches (127 mm). Its weight in air is 89·3 lb/yard (450 kg/m) and in water 63·4 lb/yard (312 kg/m). Operating pressure for the gas is 80 lb/in^2 (5·2 kg/cm^2)—higher than the external water pressure at the deepest part of the cable route, which is 139 fathoms (253 m).

The shore end cables are of similar construction to the submarine cable with the exception that the conductor size is 1·25 in^2 (742 mm^2) and the armour wires are smaller.

Installation of the Cables

The installation of the cable presents an unusual story, in that British Insulated Callender Cables Ltd are using a converted freighter which has been specially adapted for cable-laying with machinery manufactured by Telcon (Greenwich) Ltd, also a member of the B I C C group. The vessel will take on the cable, which will be stored in the holds in a continuous length, in the Manchester Ship Canal and will then sail for New Zealand for the cable-laying operation to take place. The route to be used will be between Oteranga Bay in the North Island and Fighting Bay in the South Island. The cable will be laid during the hours of daylight and the actual laying will only take a few hours. It is expected that the cables will be installed and ready for commercial service by April, 1965.

Book Reviews

Tensor Analysis of Electric Circuits and Machines. *By L. V. Bewley.* 9 × 6 *in* (229 × 152 *mm*). *Pp vi* + 309. *Illustrated. Bibliography. Index.* (*New York: The Ronald Press Co*, 1961.) Price $12 net.

In 1939 a writer of letters to the technical engineering press said he found it 'very hard to believe that the tensor calculus will ever be of real use in engineering problems'. He was by no means alone in holding that opinion at the time, but the tide of events has proved the diehards of two decades ago to be profoundly wrong in their reckoning. The present book serves to emphasise, in no uncertain manner, just how wrong they were.

Professor Bewley has brought the experiences of a dual background to bear upon the writing of this book, for prior to his present appointment in 1940 as professor of electrical engineering at Lehigh University in Bethlehem, Pennsylvania, he was with the General Electric Co of Schenectady for 18 years and a colleague of Gabriel Kron.

The book is based upon Kron's work, of which the author remarks 'in my opinion, Kron's research constitutes the most outstanding contribution to the theory of electrical engineering made in this generation and deserves to rank in importance with the work of Steinmetz. There is nothing in engineering literature to compare with Kron's generalisations as highly organised methods of attack of unlimited versatility and power. The tensor method is one of great analytical beauty which in all stages of its development exhibits a clear-cut interpretation and understanding of the underlying physical phenomena'.

With these views and other similar recognitions of the importance of Kron's work made by Professor Bewley, the present writer is in complete accord.

The book is in two parts, the first dealing with matrices, tensors, and circuits, and the second with machine analysis; there are eleven chapters in Part I and twelve in Part II. Part I may be considered as preparatory to Part II, since it covers the mathematical fundamentals of matrices and tensors and shows their use and applications in various kinds of stationary networks and plant.

More particularly, the mathematical fundamentals of Part I include studies of matrix algebra, elements of tensor analysis, tensor differentiation, and a variety of special artifices useful in the applied studies. The applicational chapters deal with the transformation of co-ordinates (as represented by network re-connections), symmetrical components, multiwinding transformer circuits, travelling waves on transmission lines, and junction-pair and complete networks.

In a similar way the mathematical fundamentals of Part II cover the uses of the Lagrange equation of motion, the Maxwell and the Maxwell-Lorentz equations of voltage (in holonomic, non-holonomic, and quasi-holonomic systems), comparisons of the general solutions employing these three methods, and the raising and lowering of indices. The chapters applying these mathematical principles to rotating machines relate to basic machine concepts, the quasi-holonomic generalised machine, small oscillations and hunting, and synchronous, induction, commutator, and interconnected machines.

As between the mathematically basic and the applicational chapters there is sometimes and quite properly no clear-cut line of demarcation for title descriptive purposes; the mathematical chapters occasionally find it necessary to give an engineering touch to the precept, while the applicational chapters sometimes extend the mathematical approach.

Quite a number of electrical engineers, both in the teaching profession and in industry, have professed not to be able to follow Gabriel Kron's original work and, very hastily and unwisely, many have spoken disparagingly of it. Professor Bewley is much more discerning when he says 'Sometimes he (Kron) became so immersed in his search for a tensor or matrix which would bring about a desired operation that he failed to notice that it could be done by inspection or by some simple device, but these things are to be expected in pioneer work and are easily forgiven. While his intuition was uncanny, it was too often substituted for a rigorous and rational development, and this can prove disconcerting to the reader'. Professor Bewley's book goes a long way towards 'rationalising' this situation.

To sum up, this is an exceedingly good book written by a man who knows his subject thoroughly and who can write clearly and to the point. The work is outstanding in the literature on engineering tensor analysis and it should enjoy a wide sale. It is beautifully printed and produced and the present writer never ceases to admire the high standard of accuracy of the typesetting by an expert compositor of involved mathematical script, such as is exhibited in this book.

S. AUSTEN STIGANT

Microwave Ferrites. *By P. J. B. Clarricoats.* 10 × 6½ *in* (254 × 165 *mm*). *Pp* 260 + *xi. Illustrated. Index.* (*London: Chapman & Hall*, 1961.) Price 50s.

This new book is intended for those engineers who require an introduction to the microwave properties of ferrites and also a treatment of the theory and principles underlying the operation and design of specific waveguide components employing ferrites. Up to the present time, because of the complexity of the propagation equations for most practical waveguide structures using ferrites, few ferrite devices have been analytically designed. The labour involved in this numerical work is however reduced by employing a modern computer, so that the theoretical design of microwave ferrite components should in the future be standard practice.

The five chapters, illustrated by 85 line diagrams, discuss successively the general properties of ferrites, the microwave behaviour of ferrites, the loss mechanisms in ferrites, the propagation through ferrites, ferrite loaded waveguides, and finally, microwave components employing ferrites. There are also 18 tables of data and 186 references for further reading and study of this specialist subject.

The treatment adopted by the author uses advanced mathematical techniques and assumes that the reader is familiar with the wave equations and their solution. The text is thus not easily digested and the contents will only be grasped after considerable mental effort by the reader. This book is thus more appropriate to the needs of the research worker and development engineer rather than those of the general reader.

The book has an attractive format and is printed on good quality paper. It is a text which should be read by those who are engaged in this exciting new branch of electrical engineering.

P. F. SOPER

Relativity for Engineers and Science Teachers. *By Laurence H. A. Carr.* 7½ × 5 *in* (191 × 127 *mm*). *Pp vi* + 52. *Index. Illustrated.* (*London: Macdonald & Co.*) Price 12s 6d.

There is a good deal more to this book than is immediately apparent, especially if one has allowed oneself to become even slightly obsessed by the universal (in the literal sense) implications attaching to the velocity of light. For then one becomes inclined at first to wonder just how, when, and where this ubiquitous quantity comes into the engineering picture . . . if it really does. Engineering structures don't move at, or even near to, the velocity of light . . . nor do their components, so then why cannot engineers concern themselves simply with Newtonian physics and leave Einsteinian to the mathematical physicists?

In nuclear engineering, *e g* particle accelerators, we are however very much concerned with the behaviour of matter moving at velocities near that of light; electric waves on transmission lines travel at practically the velocity of light; and apart from the engineer's need to keep well acquainted with related sciences, there are other features in the engineering picture that encourage a study of relativity.

This little book serves a most useful purpose in that the essence of the special theory of relativity is set out and supported by quite simple mathematics such as can be understood by any engineering student. It outlines the special theory, the Michelson-Morley experiment, relativity mechanics, electromagnetism, the three-body problem, and the summation of velocities. There is a neat exposure of the clock fallacy and the youthful traveller fallacy that will amuse engineering readers.

We believe the late author and the publishers of this book have performed a very worth-while service for those engineers and students who want a short but adequate down-to-earth account of the core of the special theory.

S. A. S.

Principles of Illumination. *By H. Cotton.* $8\frac{3}{4} \times 5\frac{3}{4}$ *in* (222 × 146 *mm*). *Pp xiii* + 526. *Illustrated. Index.* (*London: Chapman & Hall.*) Price 75s.

This new book, dealing with the fundamental principles of illumination, is a very welcome addition to the literature of electrical engineering. Illuminating Engineering has not received the attention in electrical engineering courses that the importance of the subject justifies. With far too many engineers the principle and practice of illumination is merely the use of the inverse square law, together with the inevitable 'foot-and-candle' disease which bedevils the whole subject.

Probably this state of affairs is brought about by the multiplicity of units so rampant in illumination; for instance, as the author points out in the preface, there are thirteen different units of luminance. The love of different names and units for the same quantity is all too common throughout the whole of technology. Nothing retards progress so much as language complications: different systems of units are just like different languages, and their use frequently creates confusion, dismay, distraction and frustration. The need is urgent for action to scrap all these useless units and use only the lumen and lux system, which has the merit of being a rationalised metric scheme of the same pattern as the M K S electrical units.

Although the text concentrates on presenting the principles of illumination, the author shows how these are put to practical use in modern illuminating engineering. The topics dealt with are radiation, ray optics, the eye and vision, photometry and units, illumination from point, linear and surface sources, colour, temperature radiators, electric discharge phenomena, high and low pressure electric discharge lamps, illumination calculations, daylight, and finally, street lighting.

The treatment provided is not a rehash of traditional material, but rather a sound introduction to a subject of which the engineering applications have in the past been frequently ignored. The subject is important, and the book will assist the reader with his illuminating engineering studies.

The book is well produced, attractive in appearance, easily read and comprehended. It is well recommended.

P. F. SOPER

High Voltage Direct Current Power Transmission. *By Colin Adamson and N. G. Hingorani.* 10 × $7\frac{1}{4}$ *in* (254 × 197 *mm*). *Pp xvi* + 284. *Illustrated. Index.* (*London: Garraway Ltd*, 1961.) Price 84s.

Apart from the specialists, readers of this journal have probably gained a good deal of their knowledge of h v d c power transmission from the pages of E R A Reports, C I G R E Reports, I E E Proceedings, and Transactions of the A I E E; they may even have read the serial 'D C Power Transmission' published during the period December 4, 1959 to March 4, 1960, in our esteemed contemporary, the *Electrical Journal*. But of book literature there is a distinct paucity, and in fact the present work is offered as 'the first book in the world on this important technique'.

Both authors are on the staff of the power systems laboratory of the Manchester College of Science and Technology, and this has provided them with the facilities for large-scale research and development as well as opportunities for consultation with many international specialists in h v d c. This book therefore provides an account of their own work and, inevitably, it profits from the authors' contacts with other specialists at home and overseas.

So far as the actual transmission is concerned, the book includes both overhead lines and underground cables and discusses those features which one is accustomed to find similarly important in a c transmission. Lengthy consideration is given to the terminal ends of the scheme, that is to the converters, mercury arc valves, rectifiers and inverters, including their control, compounding, regulation, and protection. All this and more besides is explained with the utmost clarity and the book is well illustrated. An extensive bibliography is given which serves to emphasise the thoroughness with which the authors have studied the various components of h v d c power transmission. The book ought to be found in every library, personal or communal, catering for the power electrical engineer.

S. A. S.

Principles of Semiconductor Device Operation. *By A. K. Jonscher.* 9 × 6 *in* (229 × 152 *mm*). *Pp viii* + 168. *Illustrated. Index.* (*London: G. Bell & Sons.*) Price 30s net.

Electronic Processes in Solids. *By P. R. Aigrain, R. J. Coelho and G. Ascarelli.* $9\frac{1}{4}$ × 6 *in* (235 × 152 *mm*). *Pp* 67 + *x. Index. Illustrated.* (*John Wiley, New York.*) Price 32s net.

These two books cover somewhat the same field, but at different levels. The first —on semiconductor devices—is a useful and well-written link between the physics of semiconductors and the purely engineering books that deal with their applications and circuits. It will appeal to workers at the graduate and research levels who wish to know more about the inner processes that occur in the various devices.

After a chapter recapitulating semiconductor theory, the author goes on to deal with non-equilibrium carrier densities; transport of excess carrier densities in a homogeneous medium; the theory of *p-n* junctions; junction diodes; and multijunction structures. The last is particularly welcome because of a growing importance of these structures in electronic modules. The work concludes with a chapter on carrier flow in inhomogeneous media.

Presentation is excellent, and the book should enable readers to obtain a clear understanding of the reasons why devices behave as they do, and also the reasons for their limitations.

The second book—Electronic Processes in Solids—is a valuable short monograph for those who wish to go more deeply into the subject dealt with in Dr Jonscher's book. Band theory and covalent semiconductors are discussed in some detail, but the parallel mathematical treatments have only been outlined. The mathematics required for this book are rather more advanced than that needed for the first work, and should be up to the level of wave mechanics, a level assumed for the reader to whom it is addressed—the fairly advanced research physicist.

J.H.J.

Digital Computers and Nuclear Reactor Calculations. *By Ward C. Sangren.* $9\frac{1}{4}$ × 6 *in* (235 × 152 *mm*). *Pp xi* + 208. *Illustrated. Index.* (*New York: Wiley.*) Price 68s net.

The digital computer is an extremely useful tool that can be invaluable for the solution of nuclear calculations. As the author points out, very few individuals can be expected to be experts in all the necessary technical fields needed for a reactor code. Two main objectives of the book under review are to provide an introduction to digital computing for nuclear engineers and physicists, and to provide an introduction to some reactor calculation problems for mathematicians and programmers.

The introductory chapter includes a discussion of the stages in the solution of scientific or engineering work on a computer, and of reactor problems giving rise to machine computations. Chapters 2 and 3 are concerned with digital computers and programming respectively, with attention given to the computer and its peripheral equipment, machine and autocode languages, flow charts and subroutines. Numerical analysis is the subject of Chapter 4, mainly devoted to the solution of non-linear ordinary and linear partial differential equations by their replacement by finite difference equations, and to eigenvalue determination. Chapter 5 illustrates all the stages for the solution of a simple fission-product calculation, including a programme for the solution of derived equations. Diffusion and age-diffusion calculations involving criticality are discussed in Chapter 6, with emphasis on multigroup diffusion equations and their approximate solution. The two final chapters include sections on the Monte Carlo method, transport equation approximations, and transient reactor, reactor physics and shielding calculations. The book is completed with a useful bibliography and an index.

A good deal of work has been surveyed in this welcome volume, and it is the opinion of the reviewer that the author has made an excellent selection of topics. The exposition is clear and reflects wide experience in the computer and reactor fields. The book will prove invaluable to people engaged in reactor calculations, and of considerable interest to applied mathematicians, physicists and those concerned with scientific computer applications.

H. GOLDENBERG

Linear Systems Analysis. *By Paul E. Pfeiffer.* $9\frac{1}{4} \times 6\frac{1}{4}$ *in* (235 × 165 *mm*). *Pp xvii* + 538. *Illustrated. Index.* (*London: McGraw-Hill*, 1961.) Price 97s.

The subtitle of this book is 'An introduction to the analysis of discrete-parameter time-invariant linear systems' and the work is intended to provide an adequate understanding of analytical theory as applied to passive linear circuits, linear electronic circuits, linear servo-mechanisms and mechanical vibrating systems. Quite properly and naturally, the book has a considerable mathematical content and the model used is a set of linear integrodifferential equations with constant coefficients. Mathematical solution is based upon the method of the Laplace transformation and the concept of the transfer function, to both of which lengthy chapters are devoted.

There are twelve chapters in the book and they cover the following ground. 1, introduction; 2, a mathematical miscellany; 3, linearised dynamic equations; 4, steady-state response to periodic driving functions; 5, an introduction to the method of the Laplace transformation; 6, systems with one degree of freedom; 7, some systems with several degrees of freedom; 8, some mathematical properties of the Laplace transformation; 9, the transfer function; 10, matrices and linear algebraic equations; 11, signal-flow graphs and linear algebraic equations; and 12, some theorems on feed-back.

In addition to what is obvious from the foregoing, particular attention has been given to the concept of the impedance operator and of phasor transformation, the unit impulse in the response of systems under impulsive excitation, and the study of poles and zeros of the transfer function.

The book is a college text and each chapter is concluded with a number of problems for solution by the reader. There is also a bibliography for further reading and a 125-item table of Laplace transforms as an appendix. We can genuinely give the work a warm welcome to the book literature on system analysis, as there is much in it that will not be encountered elsewhere.

The production, of course, is of the highest order.

S. AUSTEN STIGANT

Elements of Maser Theory. *By Arthur A. Vuylsteke.* $9\frac{1}{4} \times 6\frac{1}{4}$ *in* (235 × 159 *mm*). *Pp* 362 + *xiii. Illustrated. Index.* (*London: D. Van Nostrand Co Ltd.*) Price 71s 6d.

From the introduction of this book: 'A maser is a device in which interaction of an electromagnetic radiation field and a suitably prepared or excited sample of bulk matter results in coherent amplification of the field'. Maser is a term coined from the initial letters of the principal words in the phrase 'microwave amplification by the stimulated emission of radiation' and a maser amplifier may be a solid-state device (*e g* ruby) or a gaseous state device (*e g* ammonia).

In this book the author has presented a largely mathematical account of maser theory, dividing the study into three parts which briefly cover the following ground.

The first part (chapter 1) discusses basic phenomena accounting for maser behaviour and gives a brief description of the Behr quantum theory and of statistical mechanics. The second part (chapters 2, 3 and 4) deals with as much of the theory of quantum mechanics, statistical mechanics, and radiation theory as is necessary for further reading. The third part (chapters 5 to 8 inclusive) discusses masers *per se* and it provides a reasonably complete theoretical treatment of the basic and best understood features of the subject.

The book provides a very thorough introduction to maser theory and lays a sound foundation for further reading and for extending our knowledge of this important application of quantum theory, statistical mechanics, and radiation theory by more penetrating theoretical and experimental research. The volume is attractively produced and is a most welcome addition to what is at present a rather sparse book literature on masers.

S. A. S.

Progress in Automation (Vol. 1). *Edited by A. D. Booth.* $8\frac{3}{4} \times 5\frac{1}{2}$ *in* (222 × 146 *mm*). *Pp viii* + 231. *Illustrated. Index.* (*London: Butterworths Scientific Publications.*) Price 42s net.

This first volume of the series is devoted to eleven papers from leading British experts in the field of automation. A record is presented of the considerable achievements made in the United Kingdom on devices for industrial control. The detailed contents of the book are indicated by the following chapter titles:

1. Introduction.
2. Analogue-to-Digital Conversion Techniques.
3. Application of Electronics to Process Control Systems.
4. A Basic System of Position Control for the Traversing Tables of Machine Tools.
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8. The Ferranti System of Machine Tool Control.
9. The E M I System of Machine Tool Control.
10. Automatic Control in the Manufacture of Steel Strip.
11. Automatic Inspection.

The emphasis of this book on machine tool control is to be expected and provides interesting reading and comparisons. This is particularly so in a section of chapter 9 dealing with the relative merits of different systems. The final chapter on the implications of automatic inspection also makes stimulating reading.

H. GOLDENBERG

Statistical Theory of Communication. *By Y. W. Lee.* $9\frac{1}{4} \times 6\frac{1}{4}$ *in* (235 × 159 *mm*). *Pp* 509 + *xvii. Index. Illustrated.* (*London: John Wiley.*) Price 134s.

The author of this book is a professor of electrical engineering at M I T and the volume is the outcome of a course on the subject given by him to graduate students of electrical engineering there, supplemented by research work he has carried on in the Institute's Research Laboratory of Electronics. The book is intended as an introductory text for students and it is the author's view, with which we concur, that engineers who have not previously gone into this field will also find it of interest to them.

As the central idea in the statistical theory is that messages and noise should be considered as random phenomena, the theory incorporates probability theory and generalised harmonic analysis in its foundation. The applications of the principles and techniques of the theory have been extended far beyond communication engineering and the author cites, by way of examples, their inclusion in mechanical engineering, geophysics, biophysics, acoustics, meteorology, feedback control, aeronautics, and oceanography—a very impressive range of applied science indeed.

The text is confined to linear theory, but a chapter has been included on the synthesis of linear systems by orthonormal functions, since great importance is attached to the orthonormal representation of a linear system in the statistical theory of optimum non-linear systems.

There are nineteen chapters in the book and it is worth reciting their main themes. They are: introduction, generalised harmonic analysis, probability, random variables, averages, the Poisson distribution, time averages and ensemble averages, analytical determination of correlation functions and power density spectrums of random processes, basic concepts and tools, measurement of correlation functions and probability densities, sampling theory, detection of a periodic signal in noise by correlation, fundamental relations for a linear system and certain applications, optimum linear systems, optimum filtering and prediction, errors in optimum systems, problems in the theory of optimum systems, representation of correlation functions and power density spectra by orthonormal functions, and synthesis of optimum linear systems by means of orthonormal functions. Enough to make any mathematically-minded engineer's mouth water !

The book is really a remarkably good presentation of a subject that is by no means easy to describe. The author is both lucid and informative and we believe that very many engineers as well as students will come to regard the book as a prideful possession and a 'source book' on communication engineering.

The printing, illustrations and general format are first rate, as is usual with books from this publisher.

S. AUSTEN STIGANT

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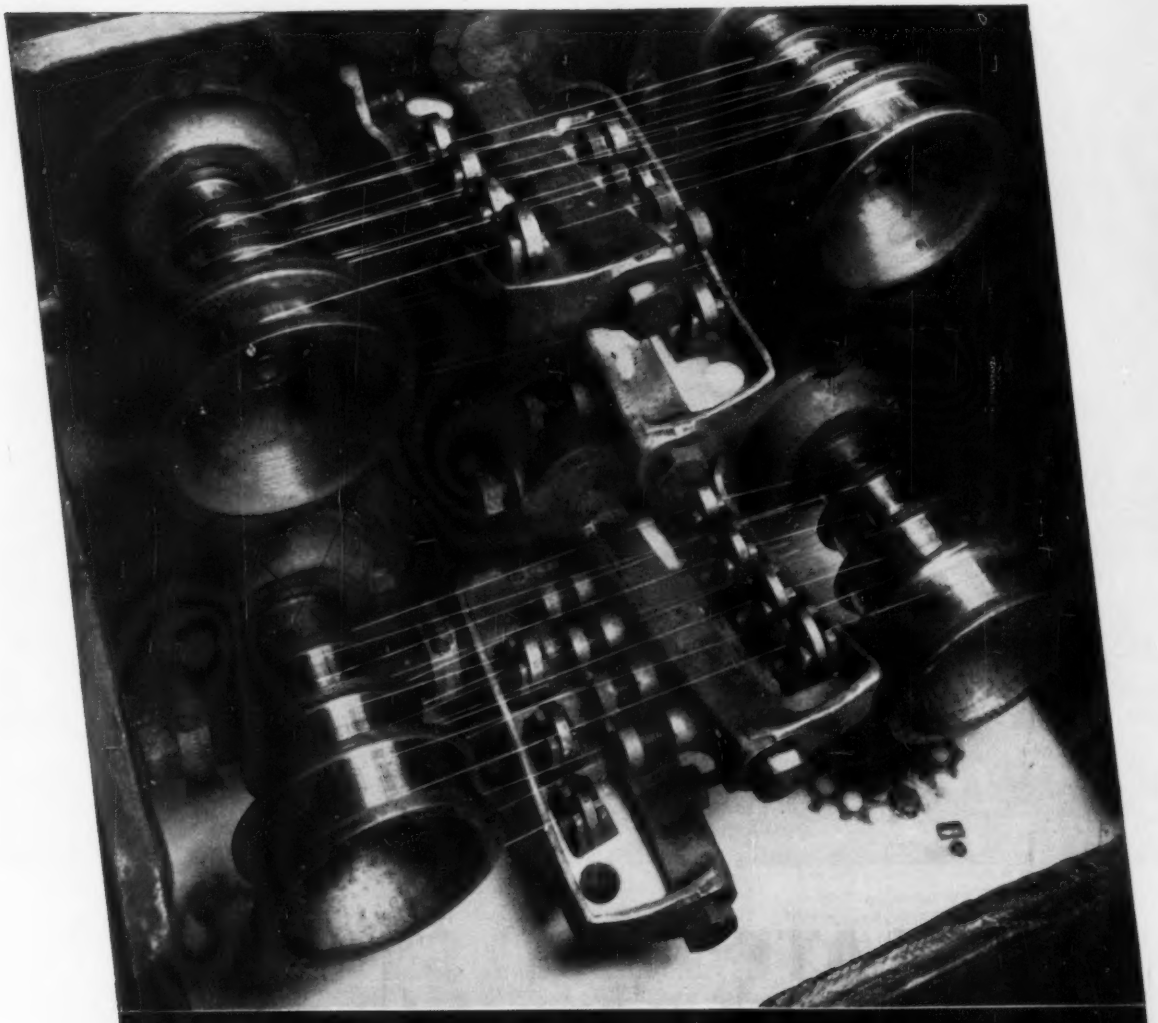

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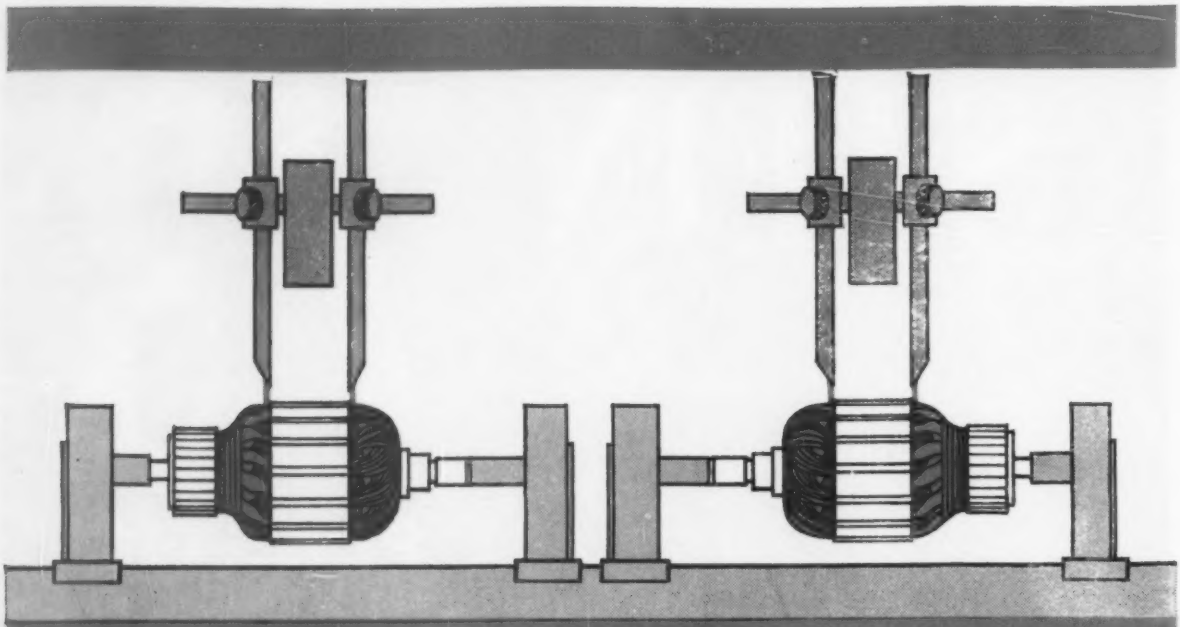

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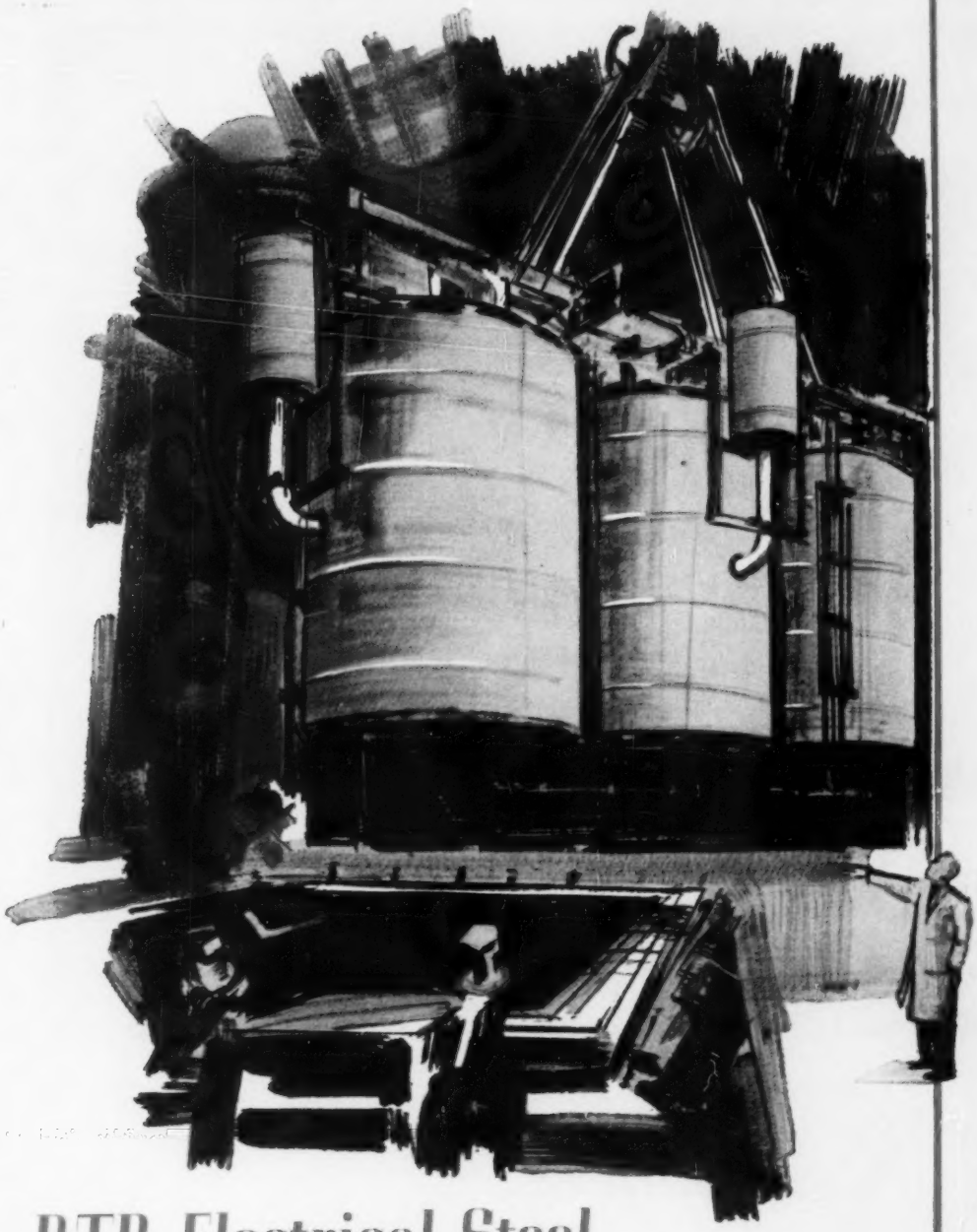

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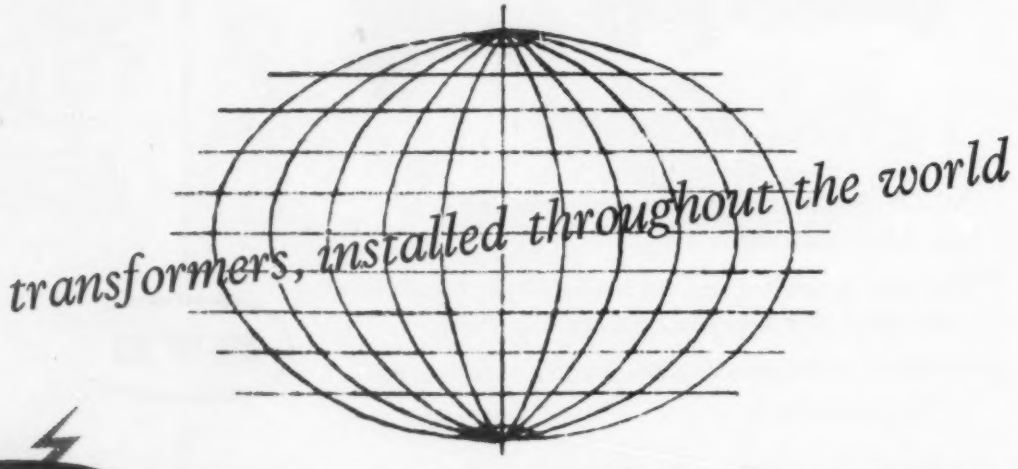

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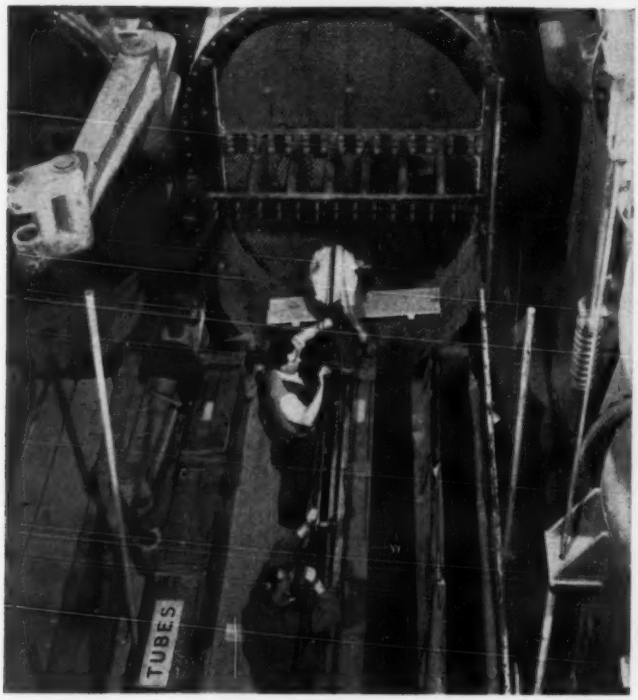

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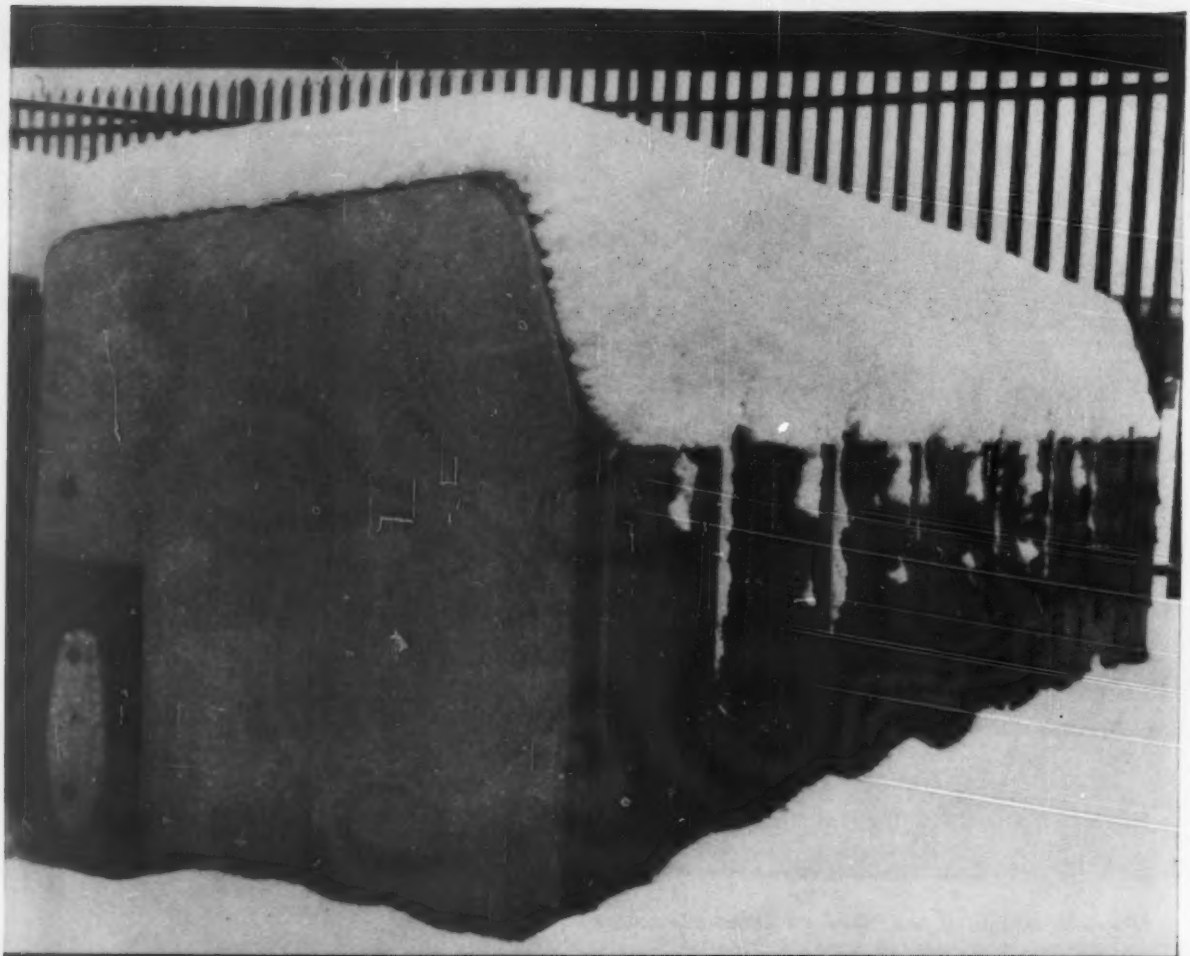

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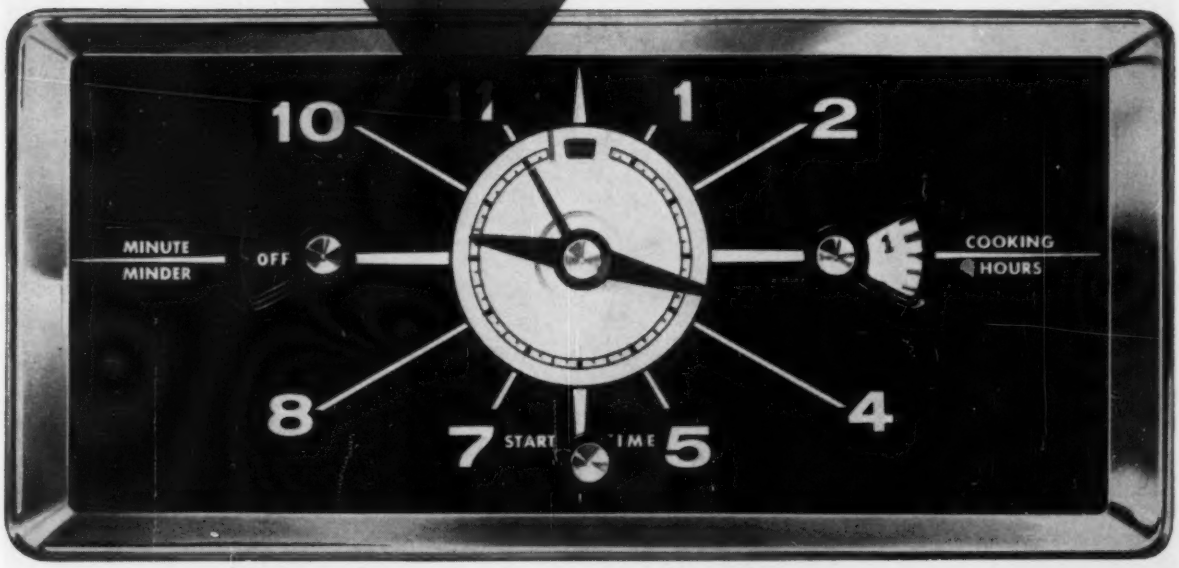

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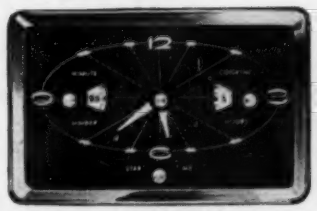

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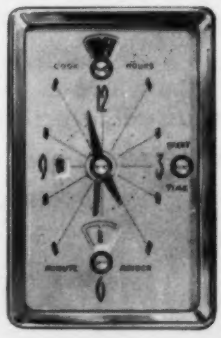

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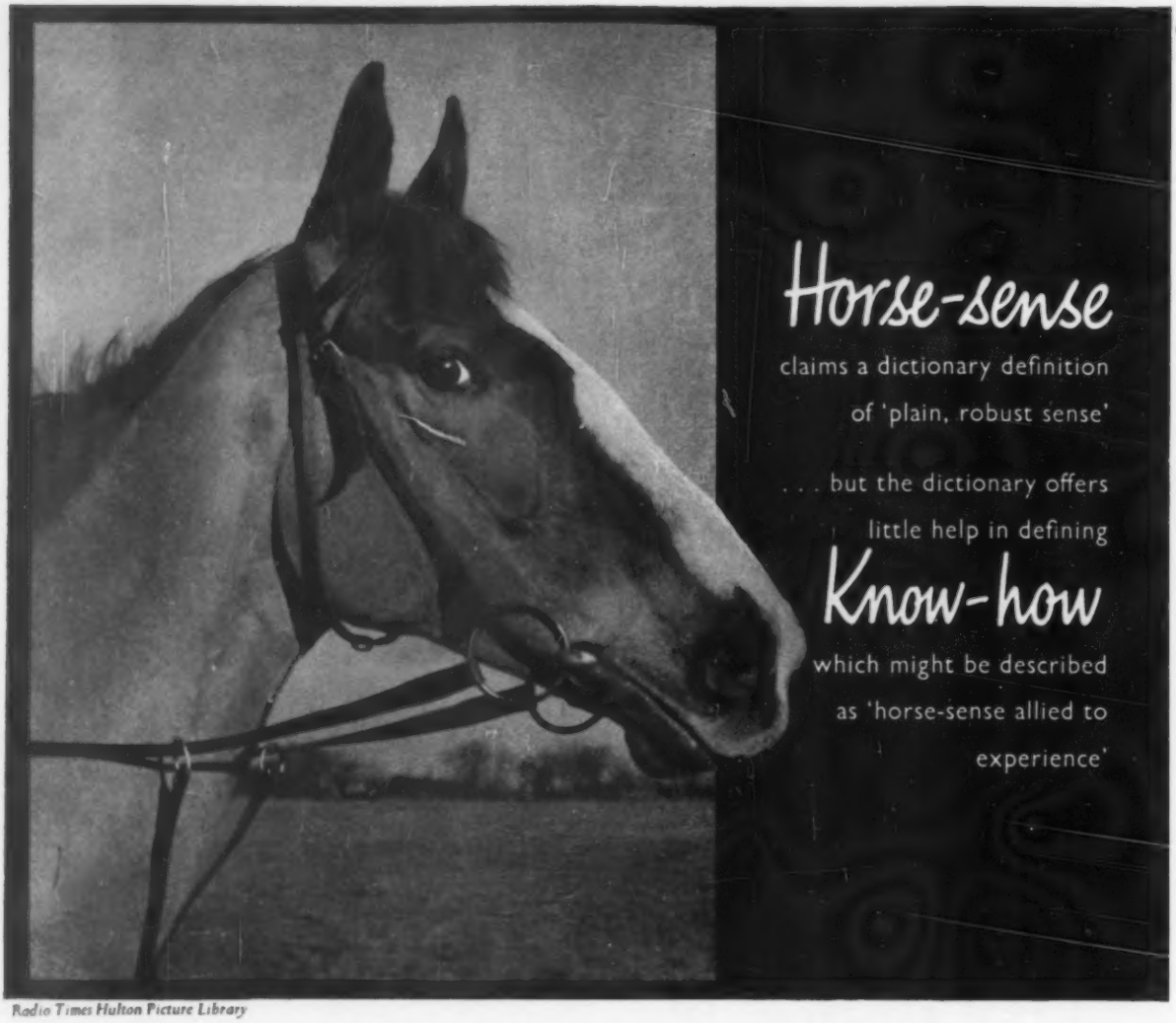

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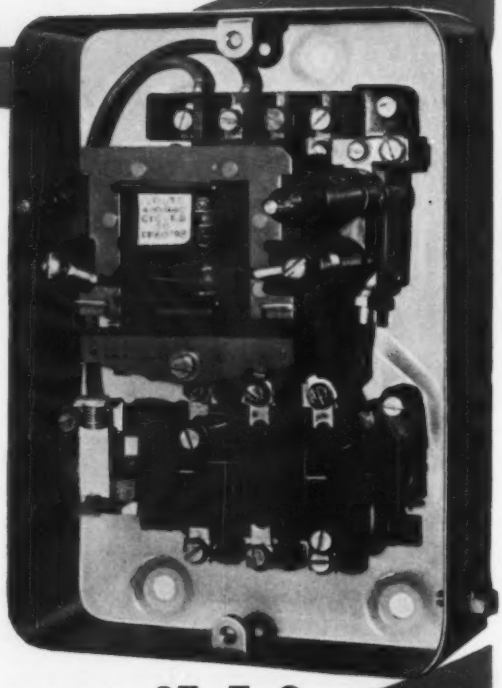

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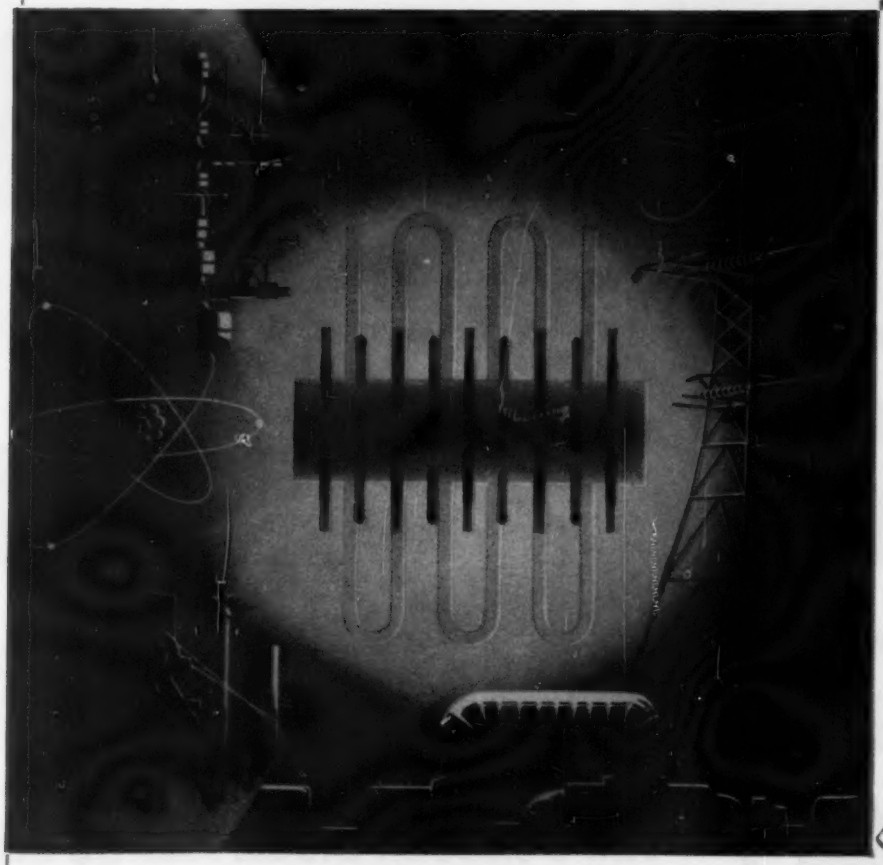

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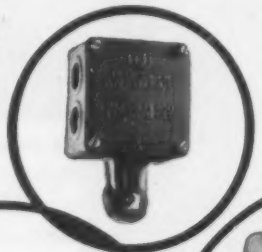

Limit Switches (Type C32L 810/1) Plunger pattern with roller on end. Roller can be moved through 90 deg. and the switch can be altered from N.O. to N.C. on site. C.S.A. approved as standard with alteration.

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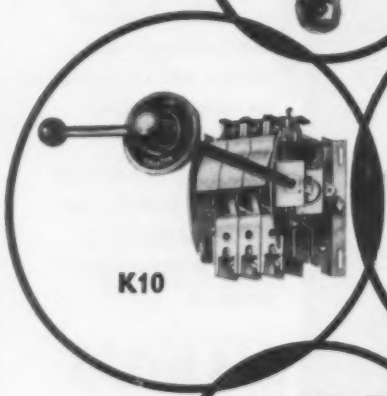

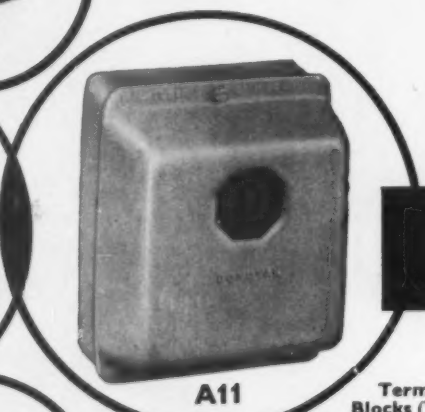

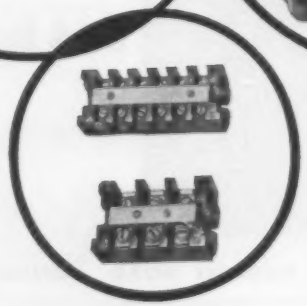

Terminal Blocks (Type J96) Clamp type terminals. White marker strip, generous clearance between phases and to earth. Sizes available: 15-amp. 550-volt. 3, 4 and 6-way. 30-amp. 550-volt 3 and 4-way. C.S.A. approved as standard without alteration.

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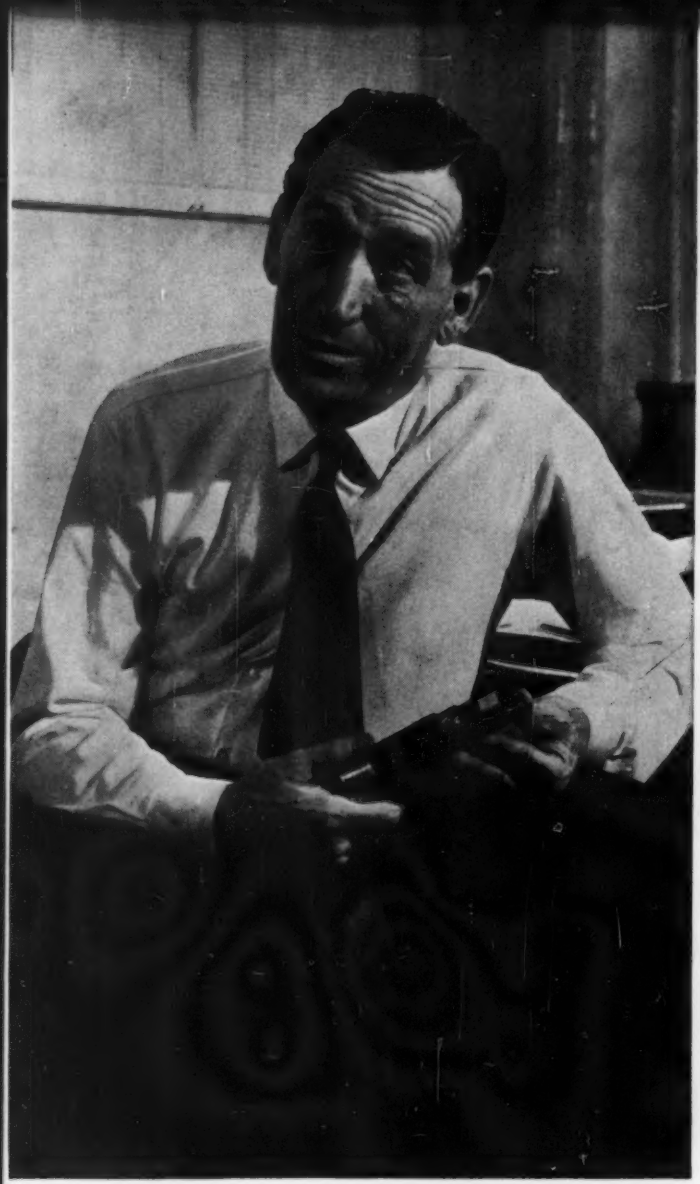

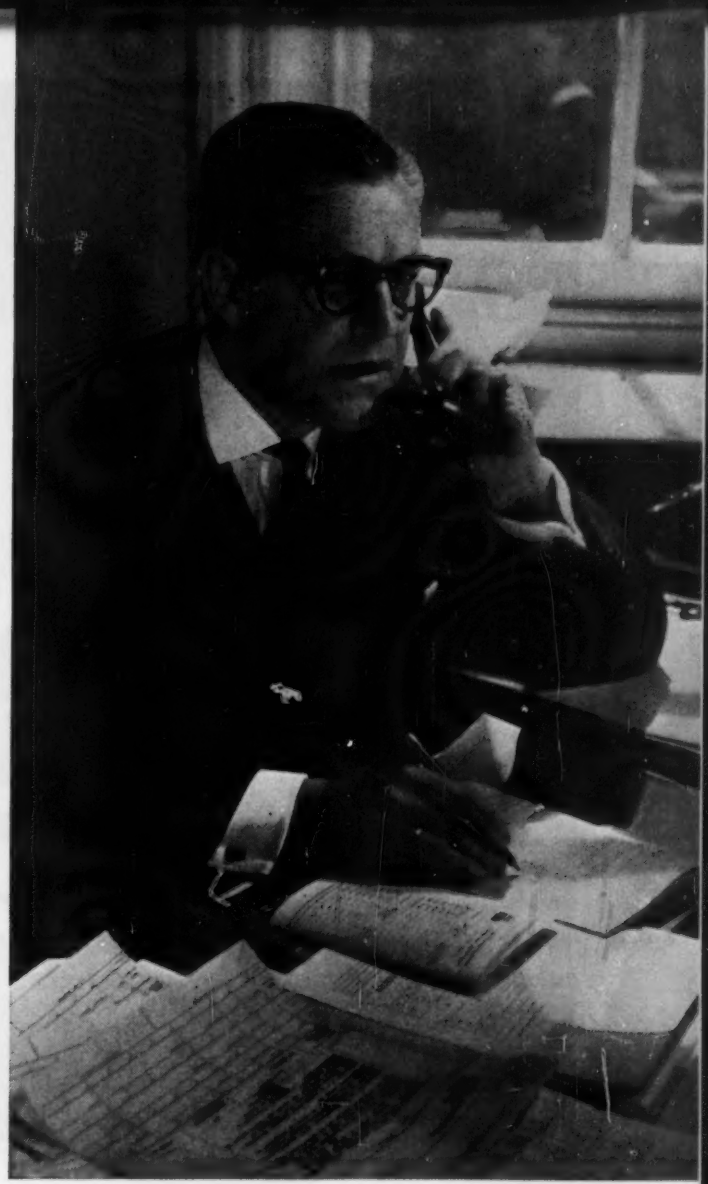

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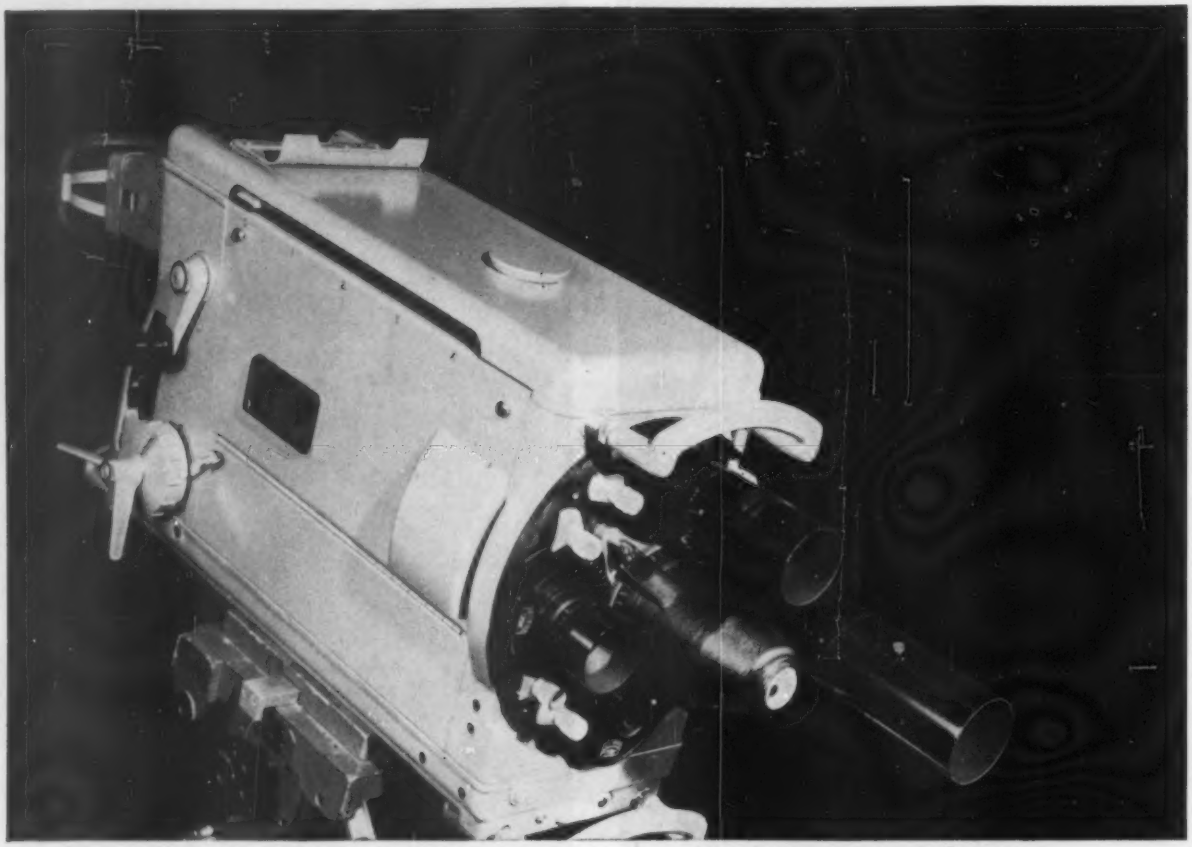

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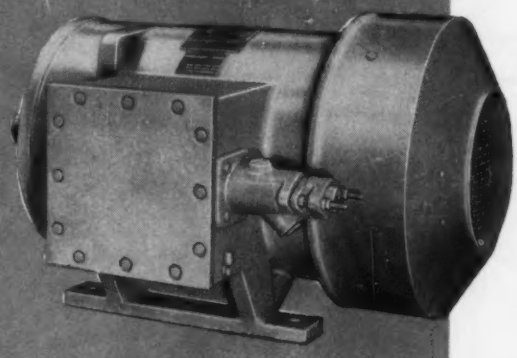

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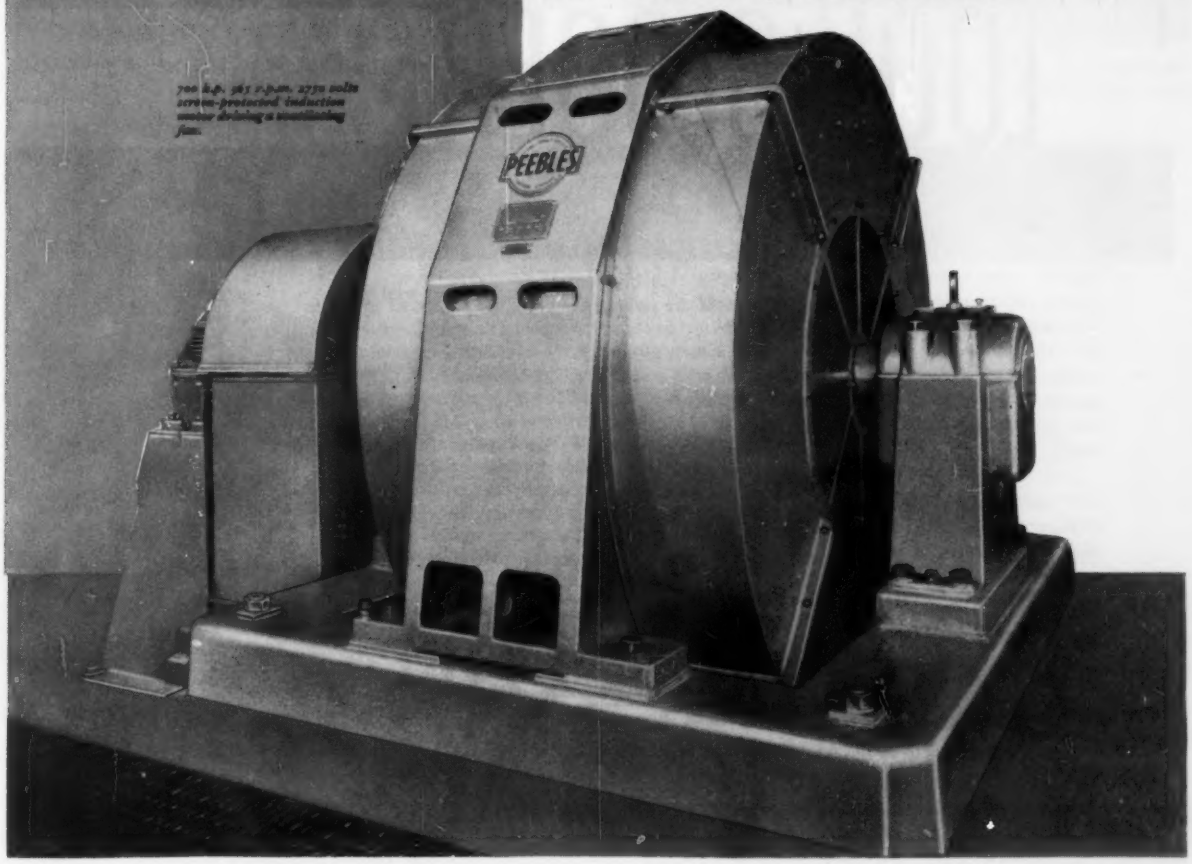

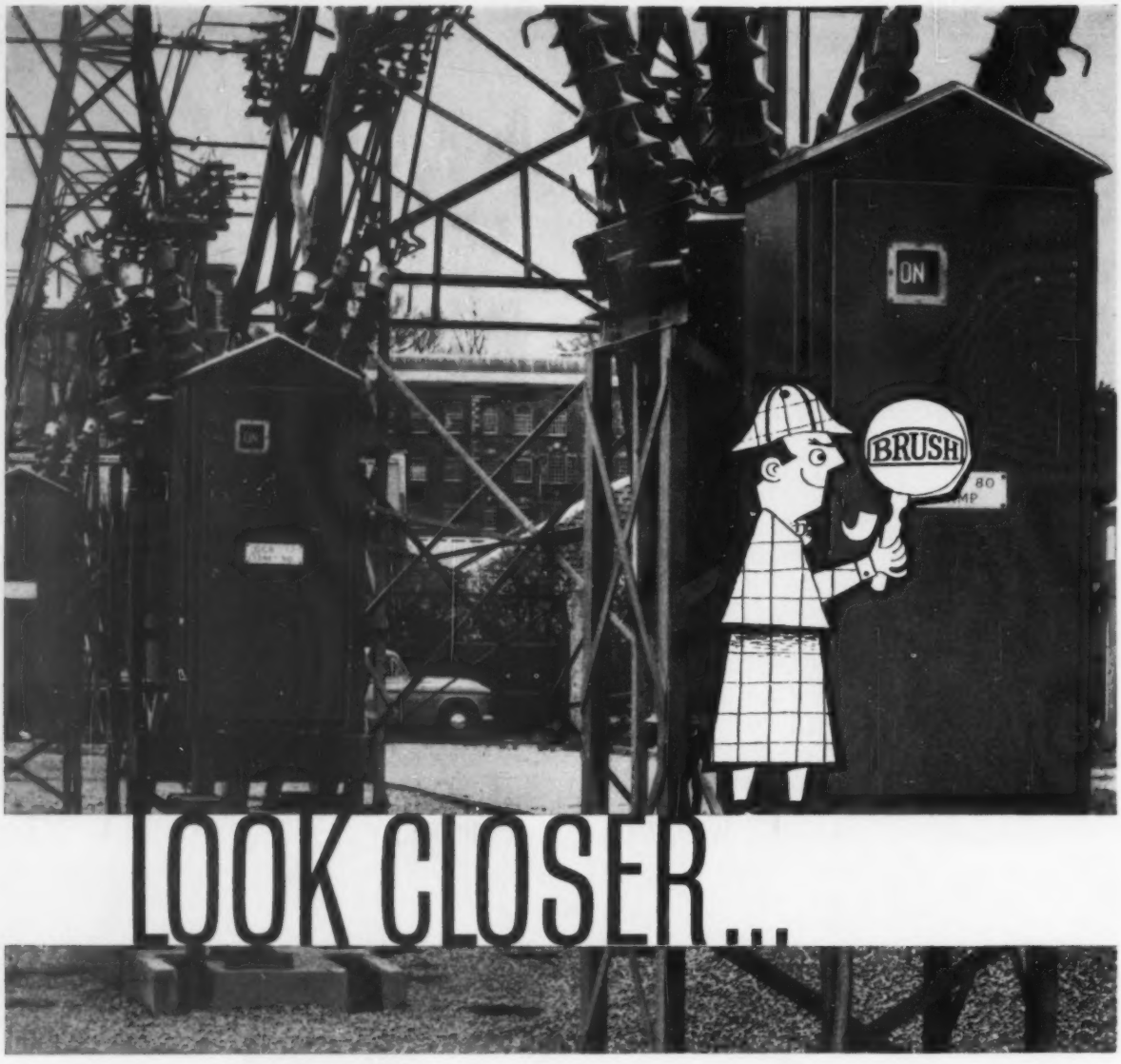

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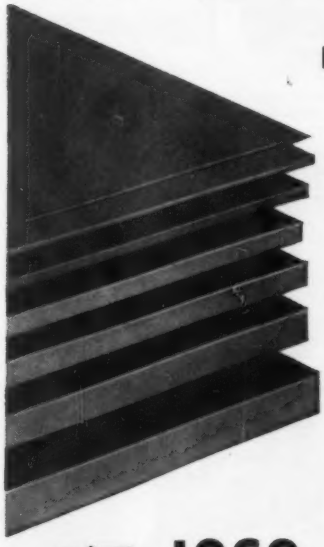

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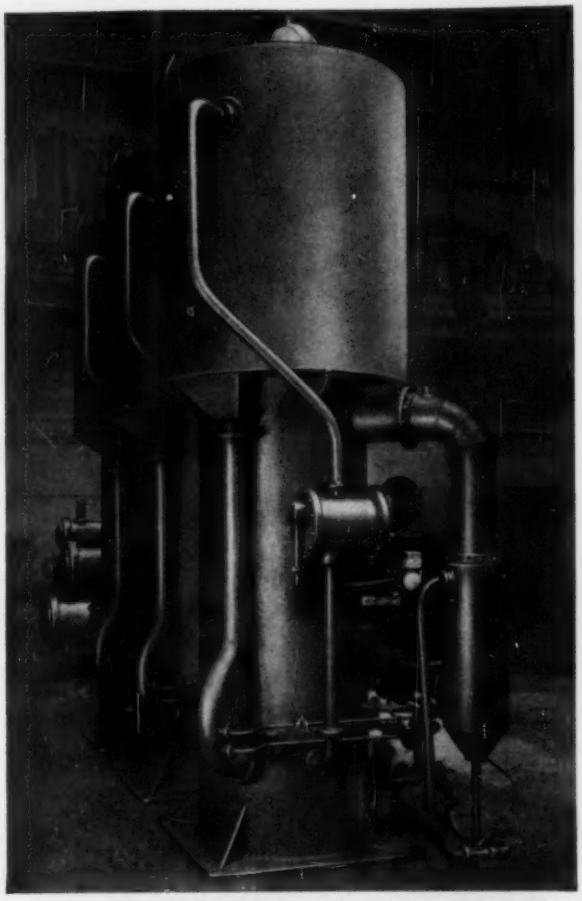

Triple effect re-compression type evaporator for 25,000 lb/hr. feed water

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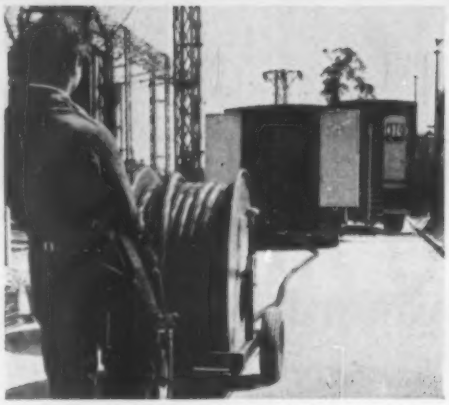
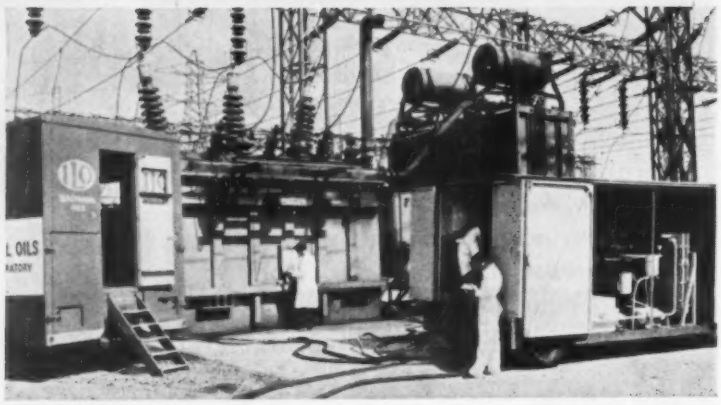
Treatment of electrical oils on site



1 Arrival on site of the ILOVAC and the laying out of its power cable for connection to supply.



2 The ILOVAC at work, drying the transformer by circulating super dried oil. The Mobile Laboratory, which controls the operation, is seen in the left foreground.

ILO

The ILO Service is a complete and comprehensive one. It will guarantee the safe and efficient running of your transformers by keeping their insulating oil always in perfect physical and chemical condition. The Castrol electrical engineers are always at your service. Their advice can be invaluable.

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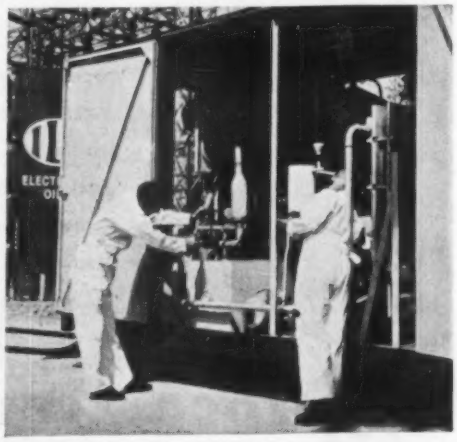

3 Two of the ILOVAC operators drawing samples of the treated oil for check tests in the Mobile Laboratory during treatment.

Everything is relative . . .

. . . including beauty, and we are sure this hippo thought the photographer as ugly as sin.

However, to both the hippo and ourselves beauty is of less importance than functional design. In the course of a few millenia the hippo has evolved a shape that is admirably designed for wallowing in muddy rivers with the minimum output of energy.

During the past relatively short period of 80 years our efforts have been largely directed towards designing fans and ancillary equipment that will perform their functions with the greatest possible efficiency, that is, with the minimum input of energy.

While we have progressed along rather different lines from *Hippopotamus amphibius*, as in nature, so in fan engineering, perfection of design is the ultimate aim, and we shall keep on trying.

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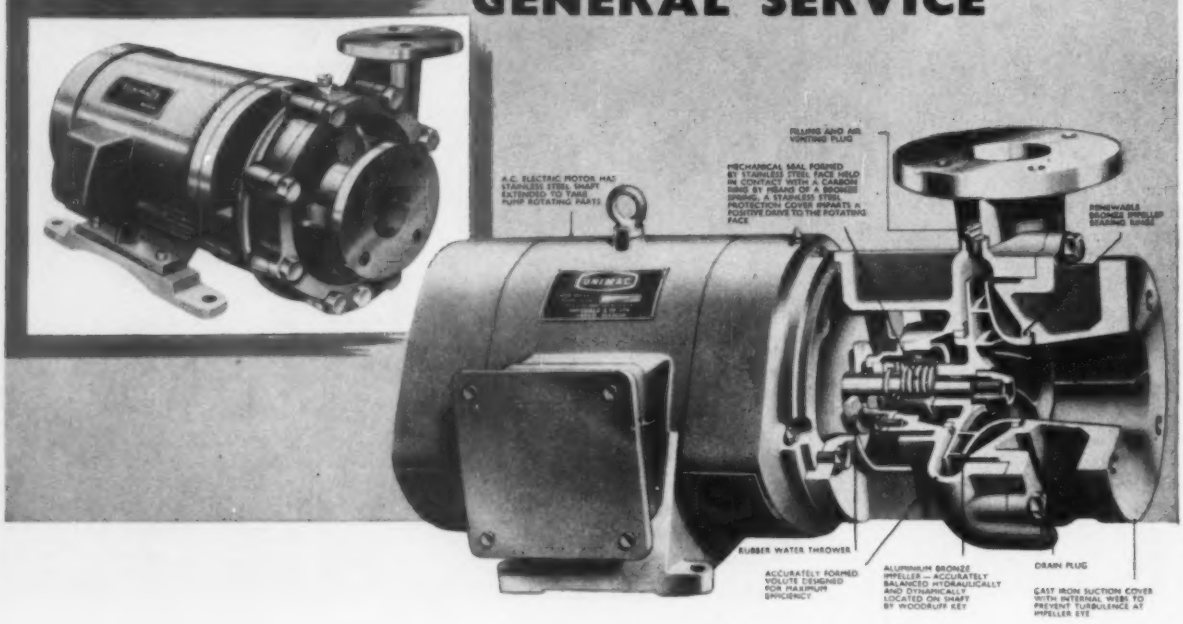
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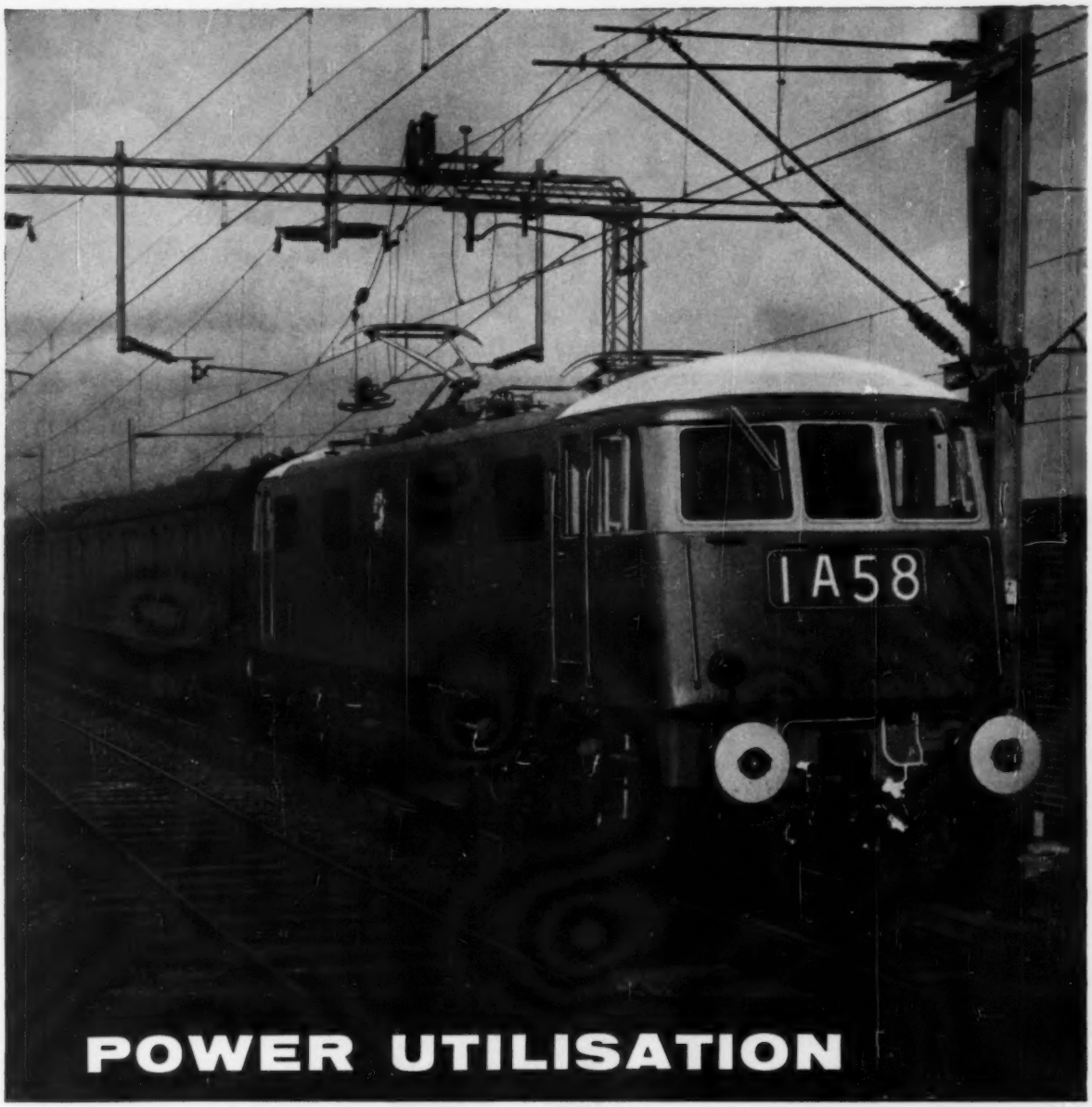

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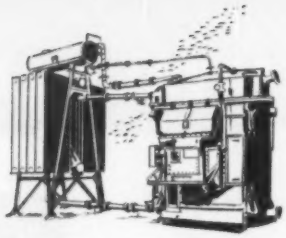
in The ENGLISH ELECTRIC Group

P.92

keep in step

.....with the Ferranti system for parallel control of transformers



Supply Engineers are aware of the importance of transformers, operating in parallel, keeping in step with each other.

The schemes developed by Ferranti for parallel control of transformers dispense with complicated circuitry involving all auxiliary relays and accurately matched components, and provide a degree of reliability not previously achieved.

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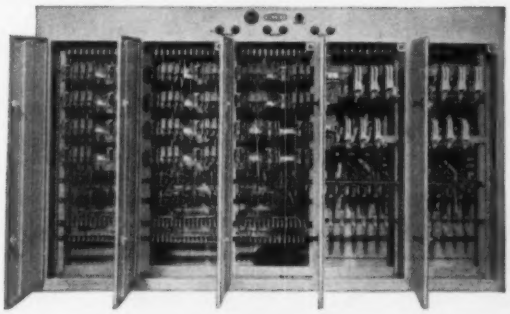

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Consider these other impressive advantages: *Unlimited full load switching*—'Hidutac' switchfuses operate at their full load current with unfailing reliability. *A unique compactness*, brought about by radial positioning of contacts. Generous wiring space and easy access to terminals at the front. *Total internal enclosure* of all moving parts, with shields over live terminals. *High fault current protection* in Single Pole and Neutral, Double Pole, Triple Pole and Neutral switchfuses with H.R.C. or rewirable fuses. Categories of duty are: H.R.C. fuses, all ratings, AC4 of BS88 (33000 amp); rewirable fuses, 15 and 30 amp ratings, S2A of BS3036 (2000 amp); rewirable fuses, 60 amp rating, S4A of BS3036 (4000 amp). *Modern styling* of pressed steel case with fully interlocked cover.

These exclusive features make 'Hidutac' switchfuses vastly superior for tungsten and discharge lighting control, motor control, and transformer and capacitor switching.

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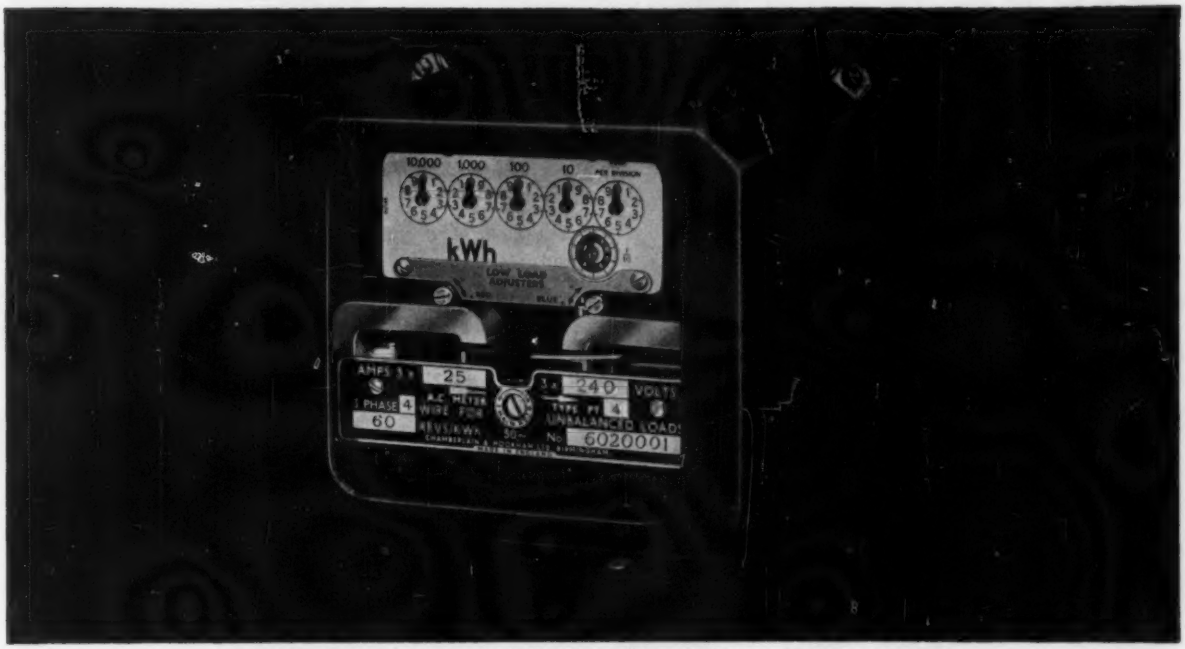

***C. & H.** P series of meters in light alloy or all-insulated cases. PT 3-phase 3-wire. PT4 3-phase 4-wire. 5, 10, 25 and 50 amperes.*

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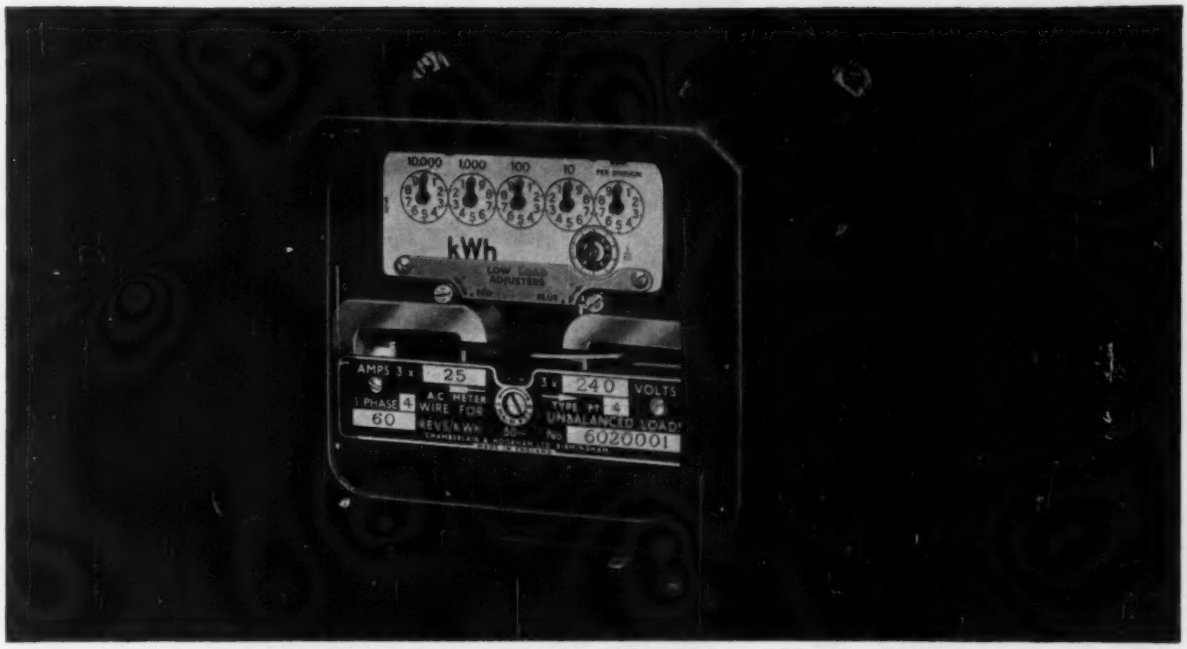

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PTU

PT4U

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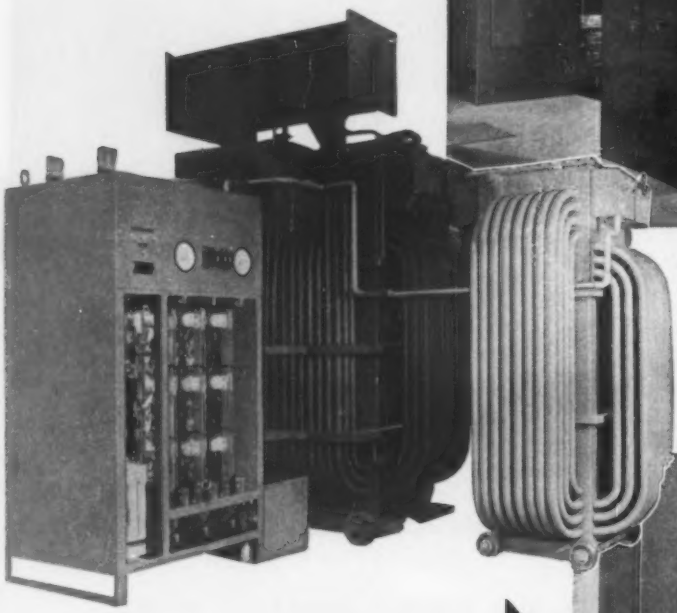

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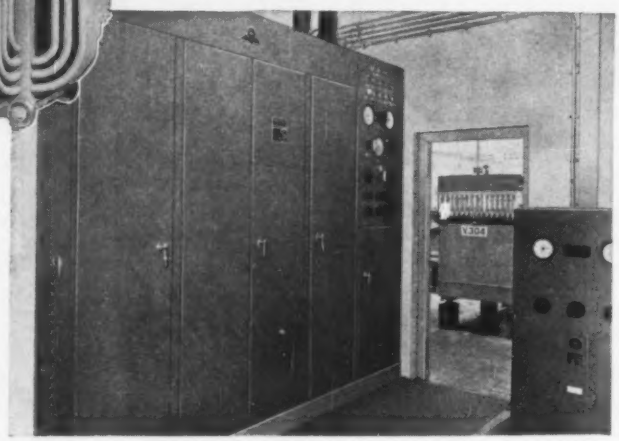

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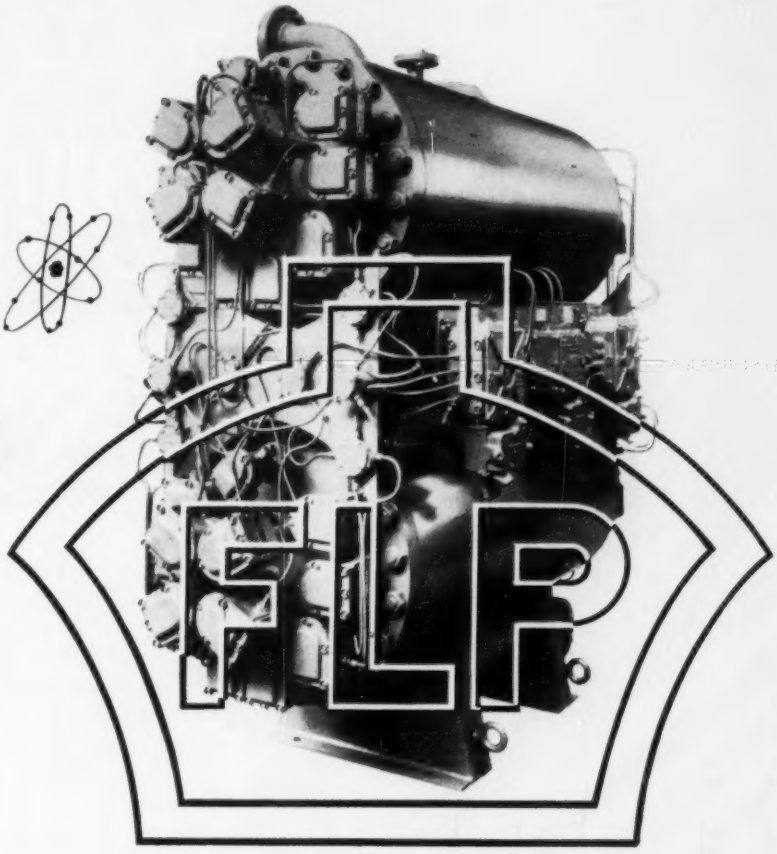

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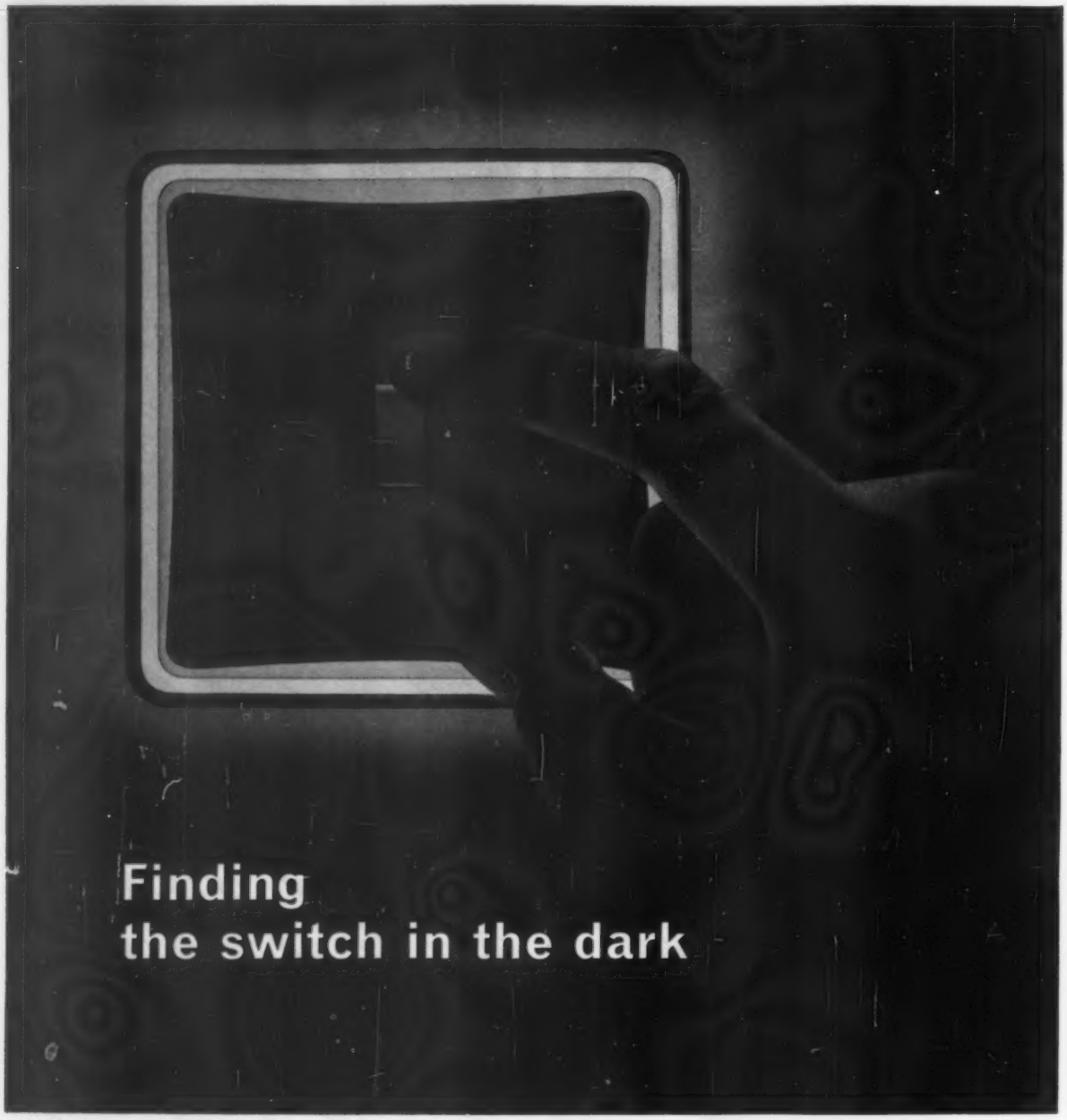

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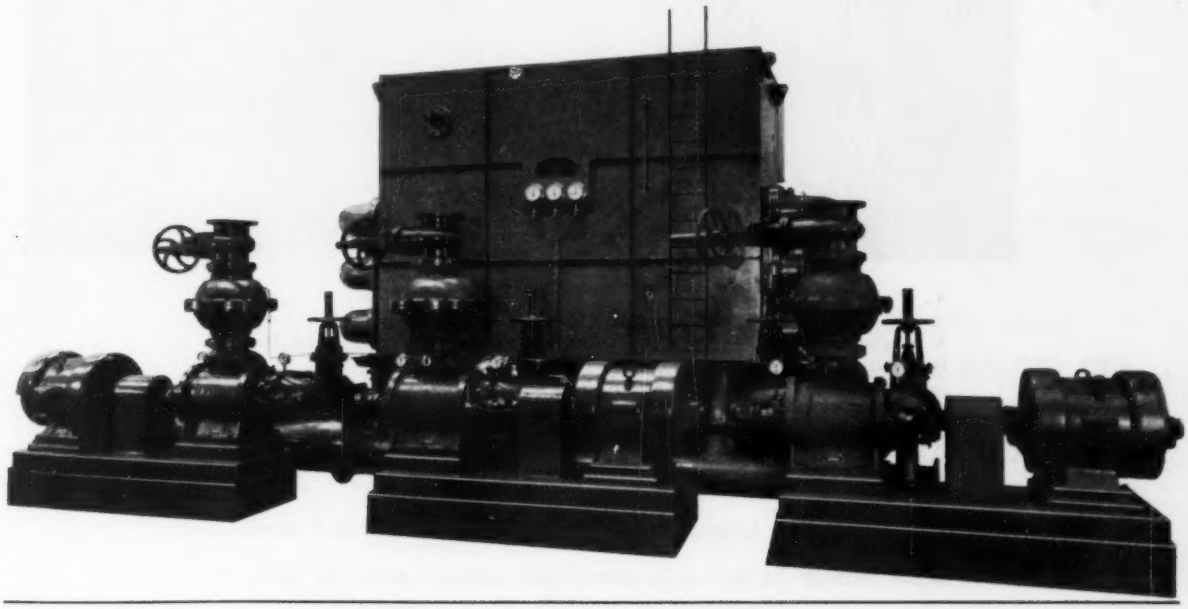

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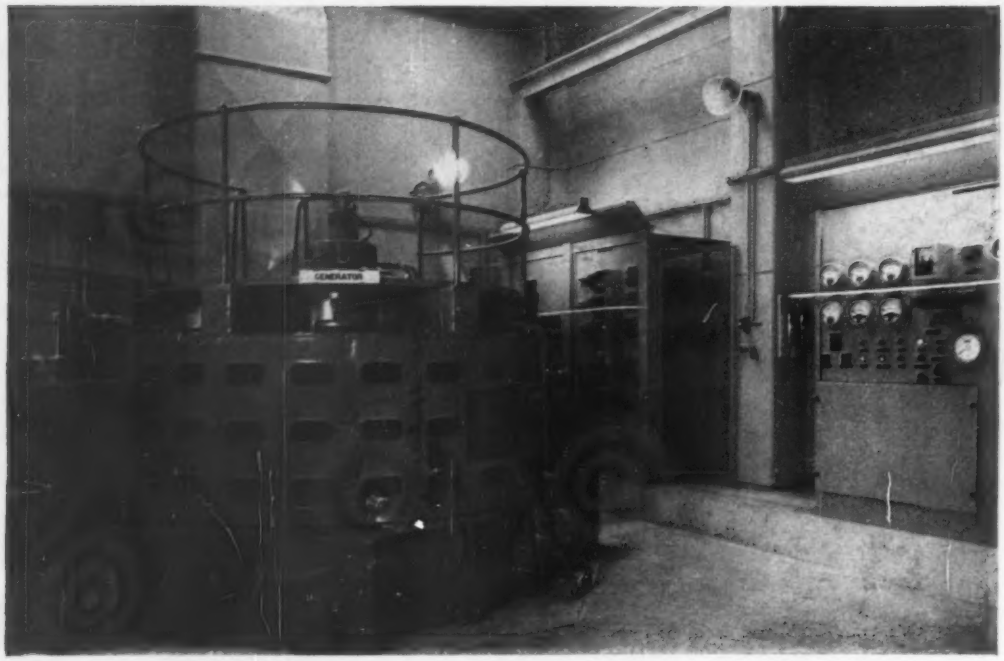

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A Mather & Platt induction generator with automatic control equipment installed in a generating station at Victoria, Australia.

The generator is a 2,350 kVA, 3-phase, 50 cycles, 3,000 volt machine driven by a water turbine at 375/378 r.p.m.

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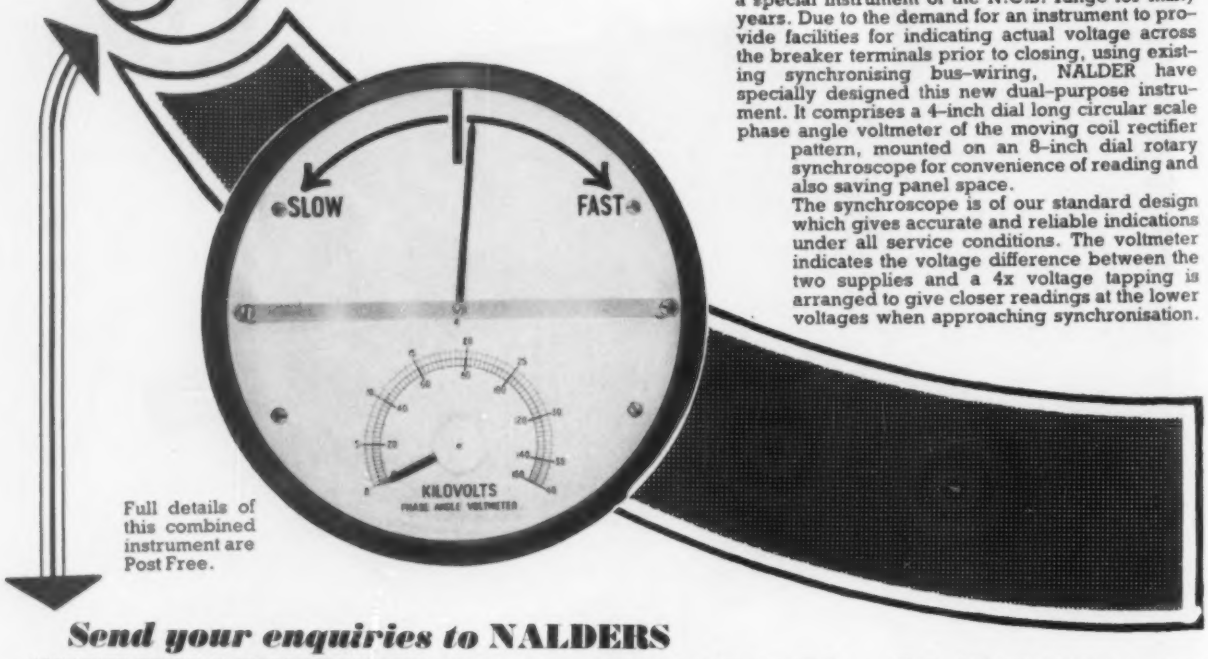

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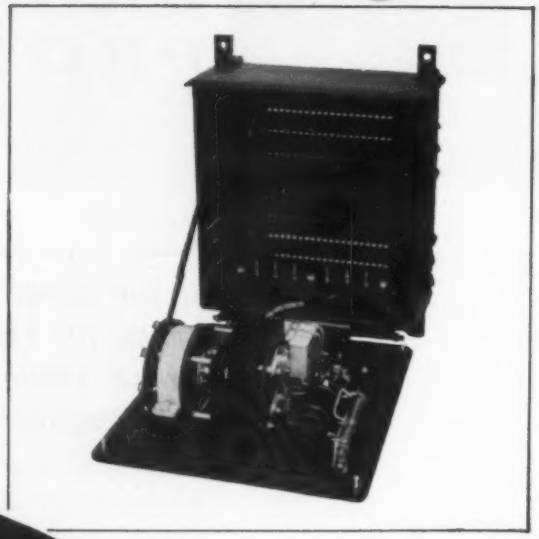

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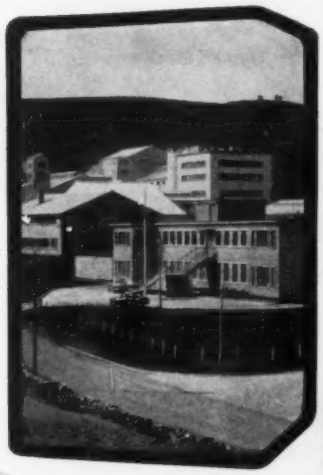

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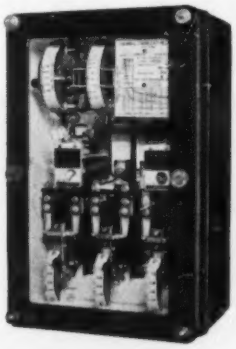

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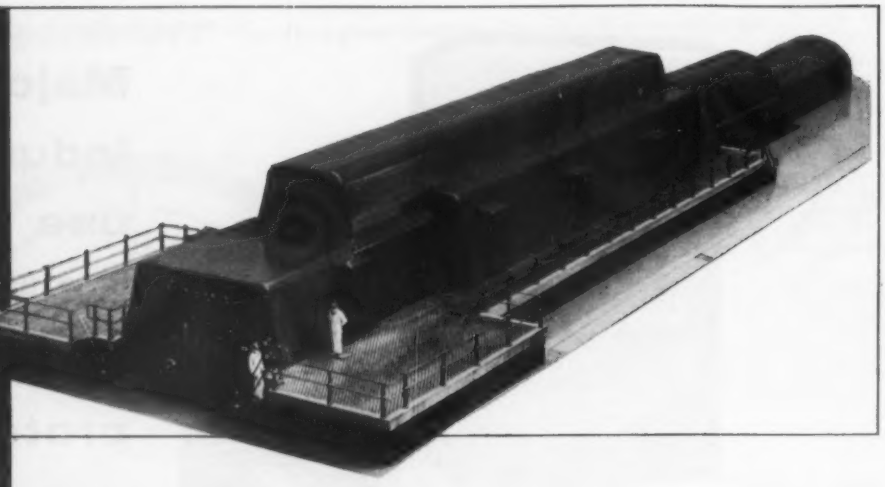
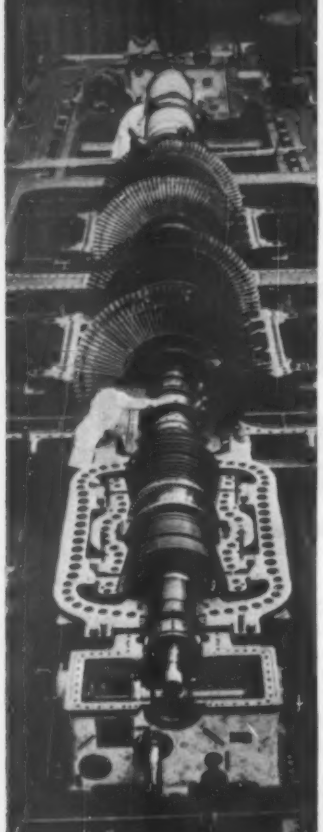


Model of PARSONS 500,000 kW single-line turbo-generator.



PARSONS large steam turbo-generators

The four PARSONS 500,000 kW single-line turbo-generators ordered by the Central Electricity Generating Board in March 1961 are alone equal to an increase of more than six per cent in the total capacity of generating plant installed at present in the United Kingdom.

The PARSONS 500,000 kW turbo-generator nearing completion for Tennessee Valley Authority, Colbert Steam Plant, U.S.A., was the first export order in the World for a 500,000 kW machine

The PARSONS 550,000 kW turbo-generator under construction for the Central Electricity Generating Board, Thorpe Marsh Power Station was the first ordered from any company in the United Kingdom.

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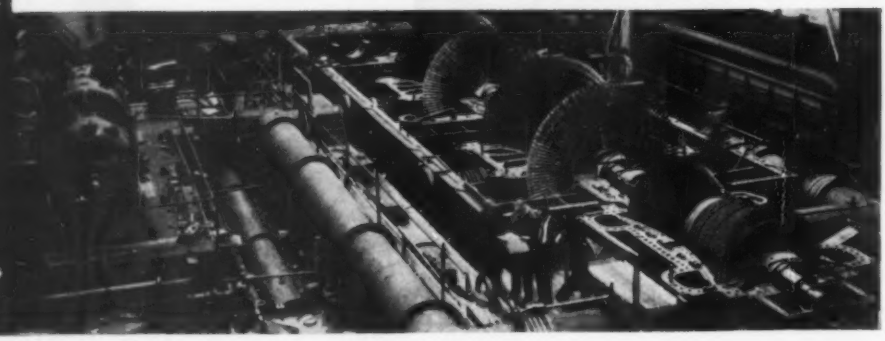
H.P. line assembly PARSONS 500,000 kW turbo-generator for Tennessee Valley Authority, Colbert Steam Plant, U.S.A.



300,000 kW PARSONS turbo-generator under construction for Lakeview Power Station, Ontario, Canada

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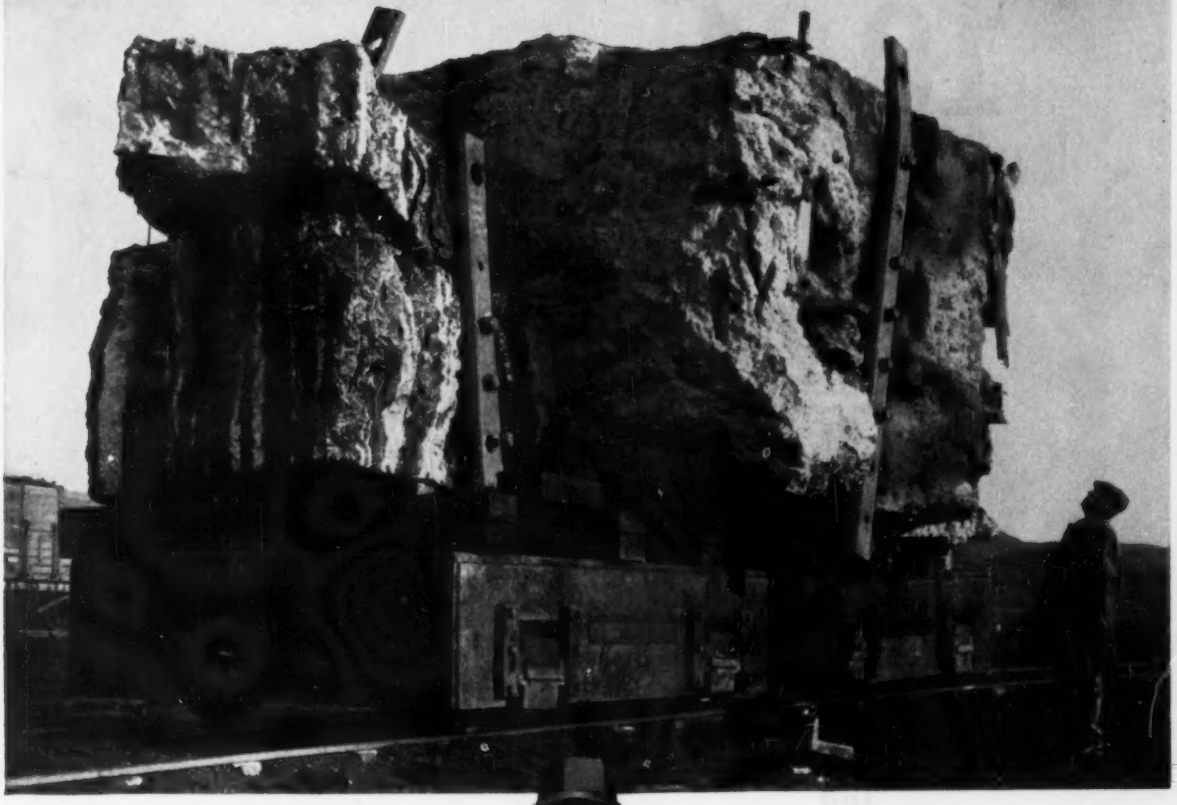

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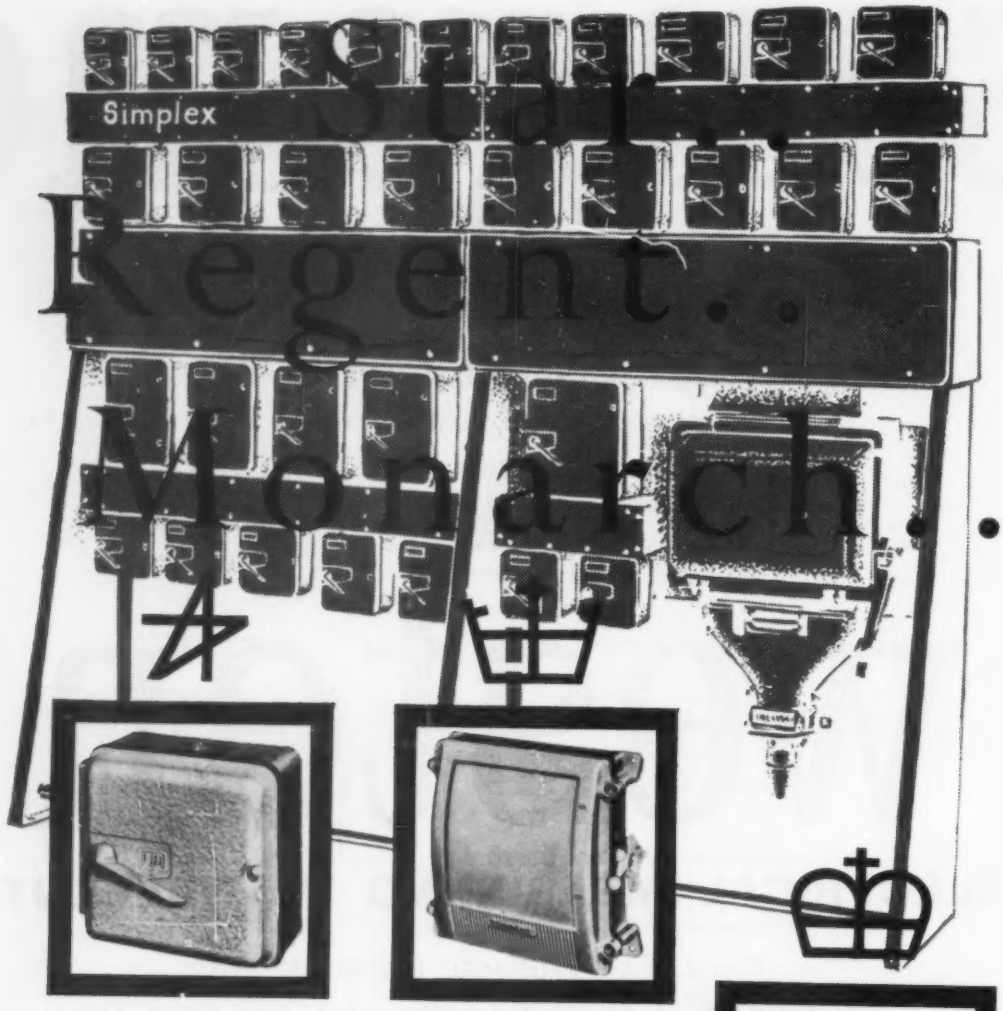

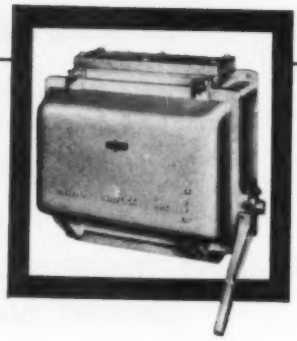

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Photographs by courtesy of The Nuclear Power Group. Bottom picture shows the 4 x Parsons 32 MW turbo-generator sets in which M & I Micanite Paxolin and V-rings are used.